THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

EDITED BY

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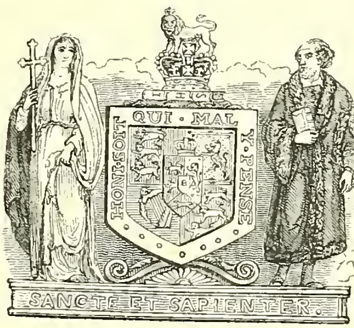


VOL. I.

A—DEA

1835—1836

LONDON

LONGMAN, BROWN, GREEN, LONGMANS, & ROBERTS.

CONTENTS OF THE FIRST VOLUME.

PREFACE.

To collect a series of Essays on all the various subjects of Anatomy and Physiology, by the co-operation of several Authors, who, as far as possible, should be selected in consequence of their special attention to, or interest in, the subject-matter of the articles which each would undertake to furnish, was the object of the Editor in projecting the "Cyclopædia of Anatomy and Physiology."

The successful inauguration of a similar work on Practical Medicine, which had advanced some way prior to the commencement of this Cyclopædia, afforded great encouragement to the Publishers and to the Editor to prosecute their design.

The first part was published in 1835, twenty-four years ago. It was then calculated that twenty parts would complete the book, and that not many years would have been sufficient for that purpose.

A glance at the Table of classified Contents will show the multiplicity of topics on which it was proposed to treat: — Anatomy, both as it regards man and all the tribes of inferior creatures, — Anatomy descriptive, — Anatomy physiological or histological, — Comparative Anatomy, — Morbid Anatomy, general and special. To these were to be added: Physiology (human and comparative); some brief notice of Vegetable Physiology; the Anatomy and Physiology of the different classes of Animals, involving, in many instances, much reference to their Zoology; and lastly Animal Chemistry, including the physiology of the fluids and secretions.

Numerous as were the articles which, according to the first plan of the work, were to have been introduced, it was soon found indispensable not only to add others quite new, but also to enlarge considerably the space allotted to each of those which formed the original catalogue, and to multiply greatly the number of illustrations.

All this was rendered necessary by the rapid strides which our knowledge of many subjects in Anatomy and Physiology began to take at the time when the earlier parts of the Cyclopædia made their appearance. Perhaps there never was greater activity of research in any branch of science during a given period, than that under which the sciences of Anatomy and Physiology advanced during the last quarter of a century. Minute anatomy, which thirty years ago was crude and undigested, now takes very high rank among the various branches of Natural Knowledge. During these years every tissue has been scrutinised; many obscure points have been cleared up; much that was wholly unknown has been brought to light. The additions to our knowledge of Anatomy, although there is yet ample room for fresh discoveries, have given a totally new phase to Physiology. From being little more than a series of vague and ill-founded hypotheses, scarcely deserving even that name, it has become a well-arranged science, embracing a vast amount of clearly defined facts, which, at once, form a solid basis for a superstructure of sound theory, and throw much light upon the various processes of animal and vegetable life.

It was the constant aim of the Editor, where it was possible, to secure the assistance of Contributors who would be likely to make original investigations, and to employ new researches for furnishing the *matériel* of their articles. Whilst it is thankfully acknowledged, that in many instances the Editor's most sanguine hopes were fully attained, it is not less true that he was sometimes disappointed, and that much delay of publication and apparent breach of faith took place. A few completely failed to fulfil their engagements, without any assignable reason; others were unavoidably prevented from so doing. In several instances the articles were not completed at the stipulated time. For some of these the Editor was content to wait, notwithstanding that by so doing the immediate sale of the book was injured, and the Editor himself exposed (with apparent justice) to charges of violation of promises. But, in the particular cases referred to, the Editor knew that delay in the completion of the articles was caused by an earnest wish on the part of the Authors to do ample justice to their subjects, and a praiseworthy scrupulousness in recording facts which they had not verified by actual observation.

To this it must be added, that for a considerable period the continuance of the work was jeopardised, and its publication wholly suspended for two years, by the death, in rapid succession, of the leading partners of the publishing firm under whose auspices the work was conducted, prior to its passing into the hands of its present publishers, the Messrs. Longman.

Nor will the Editor attempt to shield himself from blame as regards the tardy completion of the Cyclopædia. He is quite ready to confess that, in other hands than his own, it would have been long since finished. He is conscious that he has been often dilatory, sometimes vacillating, occasionally appalled by the magnitude of the undertaking, and by the knowledge of the inadequacy of his powers to carry it on to a close. At the same time, in self-defence, he feels bound to plead that, soon after the publication of the first two or three parts of the work, certain onerous duties devolved upon him, which greatly curtailed the amount of leisure available for literary pursuits. In the first place, he was called upon, at short notice, to deliver a lengthened course of Lectures on Anatomy and Physiology of a kind quite new in this country, both as regards extent and nature, which demanded a large amount of study and of personal inquiry and investigation; soon afterwards was added the responsible office of a Hospital Physician and a Teacher of Clinical Medicine; these were, at no long interval, followed by professional engagements, which, although not more responsible, created more urgent and imperative claims upon his time and attention. With all these demands upon him, it will not excite surprise that literary work often became abandoned or postponed.

At length, "per varios casus et tot discrimina rerum," the period of completion has arrived. And the Editor, while he is impressed with a deep sense of gratitude that his own health and life have been spared till the completion of the book, acknowledges, with thankfulness and pride, the invaluable aid which he has obtained from all quarters. He looks back with much of the same feelings which fill the mind of an architect who has projected a large building requiring for its completion a long series of years. While the original design, as well in its defects as in its merits, is due to himself, he is conscious how little he has had to do in supplying the materials, and completing the details of the building. For these he has trusted, and not in vain, to a body of *collaborateurs*, among whom he is proud to reckon many of the first scientific men both in this country and in Europe. How efficiently this work has been done, it is not for the Editor to say, but he deems himself justified in affirming that, for years to come, this Cyclopædia will furnish a well-stocked field for reference to the student of Anatomy and Physiology.

It is remarkable how few of the members of this little phalanx of contributors have failed to see the completion of the work! Nevertheless, we have to deplore some serious losses; and the Editor trusts he may be pardoned for offering a passing tribute to the memory of some of the more distinguished among them.

Foremost among these, although but recently removed from amongst us, was the late Dr. Marshall Hall, who furnished articles on the (to him) favourite subjects, Hybernation, Irritability. Although a veteran in science, he had finished his career before he had reached the ordinary limits of human life. To large gifts of natural genius he added an indomitable industry and perseverance. His name must always occupy a prominent position in the annals of Physiology, by reason of the active and highly successful part which he took in advancing our knowledge of the Physiology of the Nervous System, and in promoting its application to the investigation of Pathology and the diagnosis and treatment of disease; and the extremely ingenious speculations and hypotheses which he, from time to time, suggested for the explanation of various natural and morbid phenomena. The manner in which his almost latest hours were employed in applying physiological knowledge to the treatment of asphyxia shows how little it could have been said of him,

"Superfluous lags the veteran on the stage."

Still more recently, another veteran, especially distinguished in anatomical science, has fallen while actually in the ranks. Professor Harrison, having been during the previous day engaged in the duties of his chair, rapidly succumbed, in the course of a night, under an apoplectic seizure. For forty years and upwards he maintained the highest reputation as a Teacher. At a time of life long subsequent to that at which most men seek repose from such labour, he was as fresh, clear, full, and impressive, in teaching anatomy, at once the most elementary and the most important of the studies accessory to medicine, as in his early days.

The celebrated discoverer of Endosmose, H. Dutrochet, lived to the ripe age of seventy-one. The article on that subject in this work was the contribution of his own pen. It contains a summary of his views up to the time of its publication. Dutrochet's discovery has the most interesting and important bearing upon the application of physical laws to the illustration of various processes of living organisms. It gave the clue to the elucidation of many obscure points in the physiology of animals and plants, and took a lead in directing the minds of Physiologists away from abstract and fruitless speculations concerning the nature of Life, into the true path of inquiry as to the dependence of vital phenomena on chemical and physical laws.

The value of this discovery is enhanced by the recent researches of Mr. Graham, which have developed the laws of Osmose (to use his more concise and comprehensive designation), and have shown the intimate connexion of osmotic with chemical action. Further experiments on the osmotic phenomena of living animals and plants, assisted by the additional light obtained from Mr. Graham's researches, can scarcely fail to lead to important, practical results, both in Physiology and Pathology.

The loss of Newport was a heavy blow to Physiology. A man of his skill as a dissector and observer of that large and most interesting tribe, the Insects, could ill be spared. The combination of such manual dexterity and of so much acuteness of observation as Newport displayed is rarely met with. His investigations embraced at once the most delicate anatomical analyses and the deepest questions of physiology. The article Insecta, contributed by him to this work, is perhaps the most comprehensive account extant of the anatomy and physiology of this class of invertebrate animals. Newport was cut down in the prime of life, when, after many struggles and difficulties his merits were becoming recognised, and the value of his researches appreciated. There can be no doubt, had health and life been given him, he would have largely extended our knowledge of this branch of Comparative Anatomy and Physiology.

Of not less promise, in a still wider field of research, was John Reid, who for a few years before his early removal under a painful and tedious disease, filled the chair of Medicine at the University of St. Andrew's, a position in which his great powers had but a limited scope. Reid was one of those men who are content to take nothing for granted which it was at all in their power to examine for themselves. His admirable investigation of the Anatomy and Physiology of the Eighth Pair of Nerves is a model of anatomical and physiological research, scarcely equalled and not surpassed by any similar essay of recent or remoter times. His articles, Heart and Respiration, in this Cyclopædia, bear ample testimony to his scientific character, and well sustain the high reputation he had acquired even at a very early age.

The late venerable Dr. Bostock, who died at an advanced age, belonged to a different school of Physiologists from those already referred to. No man was more remarkable for the patience and depth of his literary researches. Conscientious almost to a fault, he has left a scrupulously faithful record of all that was done in Physiology up to the time at which he wrote, affording to those who take an interest in that branch of inquiry an impartial historical review of the progress of science. From the great erudition aud sound judgment of this excellent man, the Editor derived many valuable hints in the first stages of the Cyclopædia, in the plan and early progress of which he was pleased to take a lively interest.

Born a British subject, the late W. F. Edwards (also a veteran in science although he had by no means attained a great age) had spent most of his life in France and followed his Physiological pursuits there. His principal researches were directed to the observation of the influence of various physical agents upon the phenomena of Life, and the investigation of the chemical changes which occur in some of the most important and recondite vital processes. Many of his Essays, which were at first published as detached Papers, were afterwards collected, and formed his well-known work on the "Influence of Physical Agents upon Life."* Dr. Edwards's researches, whilst they determined many new and highly interesting facts, were especially valuable as promoting more philosophical views of life than those which referred all vital phenomena to the influence of a hypothetical entity.

* Translated into English by Drs. Hodgkin and Fisher, an. 1832.

An important article on Animal Chemistry in this Cyclopædia (PROTEINE) was contributed by a young and rising chemist, JOHN E. BOWMAN, whose brief career sufficed to impress his friends with a strong sense of the serious loss which society and science experienced by his early removal. His acute and well-cultivated intellect would have done much for chemistry had his life been prolonged, or had he even enjoyed, during its short span, an ordinary amount of health. But his last few years were greatly marred in their usefulness by a singular chronic malady, which slowly undermined his vital powers, and greatly limited his ability for active exertion, whether bodily or mental. Nevertheless, he has left two works which, although of small size, are of considerable practical utility to the chemical student; the one devoted to practical chemistry, the other to chemistry in its application to practical medicine.

The Editor takes this opportunity of acknowledging his obligations to gentlemen who, at different periods, rendered him the most efficient assistance in superintending the passing of the work through the press, and in other matters connected with his province.

Dr. ROBERT WILLIS, formerly of London, now extensively engaged in medical practice at Barnes in Surrey, for many years took an active part in the superintendence of the printing of the work, and contributed largely to the Bibliography appended to most of the articles, as he was so well qualified to do by his extensive knowledge of books. Dr. Willis also contributed the article ANIMAL. Upon his retirement, the Editor derived similar valuable assistance from his friend and former pupil, Mr. S. ROOD PITTARD, who also contributed several articles. And, subsequently, Dr. HYDE SALTER, now well-known, and of deservedly high reputation as a Physiologist and Physician, kindly afforded his aid in the same way, as well as by his valuable contributions of the articles PANCREAS and TONGUE.

This seems the fitting place to state that it has been found necessary, in a few instances, to depart from the strict alphabetical arrangement, either by placing articles under names not commonly used, or by clubbing together two or more subjects, to which it would appear, at first, more natural to have devoted separate articles. The necessity for such modifications arose out of contingencies to which all works are liable, when they are published in Parts, and dependent for regularity of publication on the punctual contribution of the various articles. Where such punctuality could not be obtained, and where it was found absolutely necessary to curtail delay, the changes above alluded to were adopted as a matter of necessity rather than of choice. Thus, Ear is referred to HEARING, ORGAN OF; Kidney to REN. The union of certain articles together under one heading was sometimes found both convenient for treating the subjects, and œconomical of space. Thus, the Anatomy of the Brain was conveniently associated with that of the Spinal Cord, and will be found under NERVOUS CENTRES; that of the Intestinal Canal under STOMACH AND INTESTINAL CANAL (Dr. Brinton); and that of the Ovary in the elaborate article of Dr. Farre, UTERUS AND ITS APPENDAGES. SEROUS AND SYNOVIAL MEMBRANES have been treated of under one heading, from the close analogy of their structure; and Hairs, Nails, Skin, &c., are described under the general title TEGUMENTARY ORGANS.

It was found absolutely necessary, owing to difficulties which otherwise must have completely prevented the completion of the work, to place several articles in a supplementary volume, regardless of strict alphabetical arrangement. But it is hoped that for this, as well as the other departures from the strict Encyclopædic form, compensation will be found in the various Indices, and in the Table of Classified Contents.

26 Brook Street, Grosvenor Square, London,
Jan. 1859.

CLASSIFIED CONTENTS

OF

THE CYCLOPÆDIA OF ANATOMY AND PHYSIOLOGY.

HUMAN ANATOMY, DESCRIPTIVE.

HUMAN ANATOMY, SURGICAL OR TOPOGRAPHICAL.

ANATOMY, GENERAL OR PHYSIOLOGICAL.

ANATOMY, ABNORMAL AND MORBID.

ANATOMY, COMPARATIVE.

ZOOLOGICAL ANATOMY AND PHYSIOLOGY.

PHYSIOLOGY.

ANIMAL CHEMISTRY, PHYSIOLOGY OF THE FLUIDS AND SECRETIONS.

GENERAL SUBJECTS.

THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

ABDOMEN, (in anatomy,) with which the terms *venter* and *alvus* are sometimes used synonymously. Gr. γαστηρ. Germ. *bauch*, *unterleib*, *hinterleib*. Ital. *ventre*, *pancia*, *abdomine:* the French anatomists use the word *abdomen* as we do, and also the term *ventre* as we do *belly;* also *bas-ventre*. It is so called, " quod *abdi* et tegi soleat, aut quod alimenta in eo *abdantur*, aut intestina ibi sint *abdita*."*

The term denotes a particular region and cavity in a large proportion of the animal series, being found in most of the classes from Mammalia down to Articulata. It is impossible to give such a definition of this region as will apply to all; it appears, however, to have one property sufficiently general, viz. that it contains in all these classes more or less of the digestive organs. Thus, to ascend from the Articulata:—

It is in the class Insecta of the Articulata that we find the most defined region bearing this name. This region is the most posterior of the three portions into which the body of an insect is divided, and is composed of a series of segments which unite to form a cavity enclosing the viscera subservient to nutrition, respiration, and reproduction; it does not contain any of the organs concerned in locomotion. It is composed of a series of simple hoops, united to each other by a ligamentous connexion, which allows the abdomen to be flexible or otherwise, according to the closeness of the union.† The abdomen is united by its anterior extremity to the thorax. (See INSECTA.) In the Arachnida there is also a similar division of the body, to which the name of abdomen has been applied, united in front with the cephalo-thorax, and separated from it by a deep groove, which leaves only a slender pedicle between them; like that of the Insecta it contains the principal viscera. (See ARACHNIDA.)

In all the divisions of the Vertebrata there is an abdomen. In fishes the abdomen is situated towards the posterior extremity of the body, and is separated from the heart in front by a strong membrane analogous to the diaphragm; it contains the digestive and generative organs. In reptiles the abdomen is that region which lies immediately anterior to the anus; in many classes it is not separated from the cavity containing the lungs, so that the lungs, heart, organs of digestion and generation are all contained in one great cavity; in the crocodile, however, a layer of muscular fibres, having the appearance of a diaphragm, covers the peritoneum, where it is connected with the liver, so that the lungs do not project into the abdomen. In birds, the abdomen extends from the posterior extremity of the sternum to the anus; it is, as in fishes, separated from the thorax by a membrane which, though not muscular, is analogous to the diaphragm, but is perforated so as to allow the air to pass into the abdominal cells. In Mammalia, the abdomen is placed between the pelvis and thorax, with the former of which it is continuous; but it is separated from the latter by the diaphragm; its principal contents consist of the digestive organs, and its size varies in reference to their respective degrees of development.

* Facciolati, in verb.

† See a very good engraving from Carus, of the segments of an insect, in Roget's Bridgewater Treatise, vol. i. p. 321.

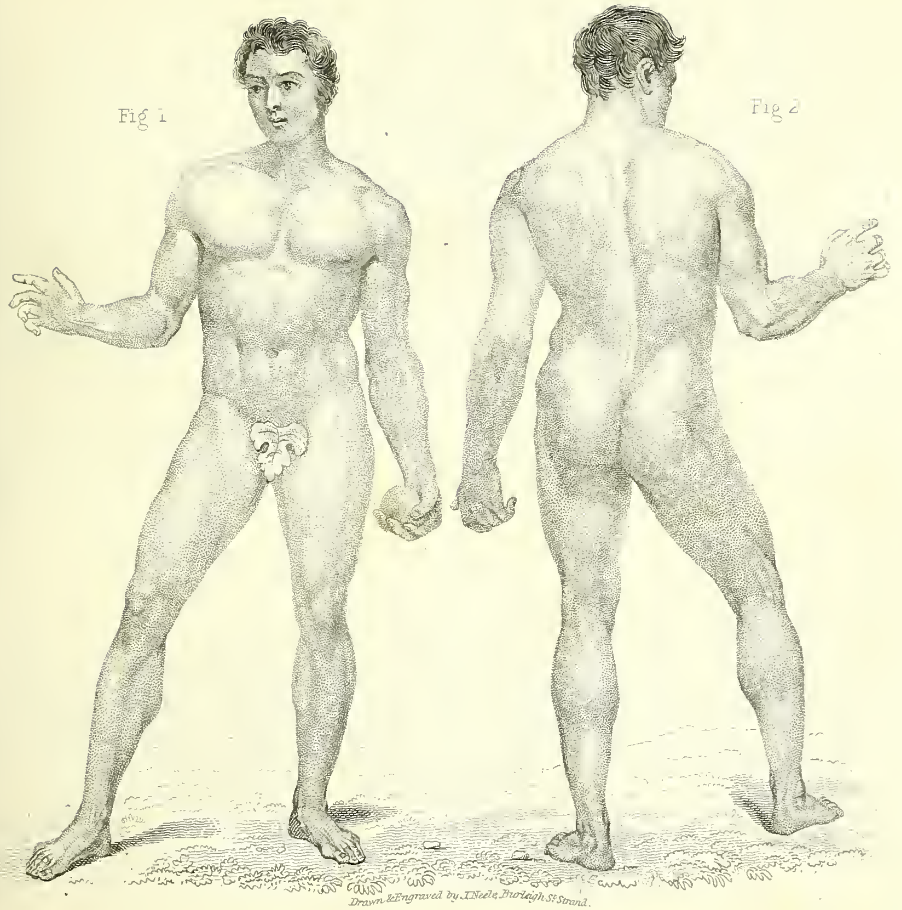
ABDOMEN (in human anatomy.) In examining the human skeleton, we notice that from the apex of the thorax to the inferior outlet of the pelvis, there exists one great oblong excavation. The two superior fifths of this cavity are separated from the remaining portion in the entire subject by a musculo-tendinous lamella, which, thrown into a vaulted form, constitutes the partition between the cavity of the thorax above and that of the abdomen below. This latter cavity communicates inferiorly with the space circumscribed by the ossa innominata, denominated the cavity of the pelvis; nor is there any natural line of demarcation between the two cavities. The communication between the two cavities is as free in the recent subject as it is in the skeleton, and under various conditions the contents of those cavities pass from the one to the other. A plane extended horizontally from the linea iliopectinea on one side to the corresponding line on the other would constitute an artificial floor to the cavity of the abdomen, properly so called, and a limit between it and the pelvis; and this artificial division of a cavity, naturally single, may be useful in describing the positions of viscera, but to understand the functions of the abdomen, it will be expedient to consider that cavity and the pelvis as one. Some anatomists object to the use of the term cavity as applied to the abdomen, because no cavity can be said to exist, except in the skeleton or in the eviscerated subject; neither can there properly be said to be a cavity of the thorax or of the cranium, inasmuch as that cavity is obliterated so long as the viscera are in a state of integrity. I apprehend that the objection is hypercritical, as it must be evident that the cavity does not become apparent till the viscera have been removed; nevertheless, it is perfectly correct to say that it contains the viscera, nor is it incorrect to make use of the expression "anatomy of the abdominal cavity," to imply the anatomy of its contents when in their natural position. Hence, then, we derive a natural subdivision, in treating the subject of this article, into two heads: 1. the anatomy of the walls of the abdomen; and, 2. the anatomy of the cavity of the abdomen.

I. *Of the walls of the abdomen.*—One of the most striking differences between the abdomen and the other great visceral cavities consists in the small proportion of bone that exists in its walls. The osseous boundaries of the abdomen may be thus enumerated: superiorly, towards the posterior and outer part, the false ribs; posteriorly, the lumbar region of the spine, which by its transverse processes affords strong points for the attachment of muscles, and by the bodies projects into the cavity, forming an imperfect septum, slightly convex on its anterior surface, and dividing the cavity into two symmetrical portions. Inferiorly, the alæ of the ilia afford lateral expansions, which support some of the contents of the abdomen, and the pelvic brim completed behind by the promontory of the sacrum, forms the opening by which the cavity of the true pelvis communicates with that of the abdomen. Between the inferior margin of the thorax and the superior margin of the false pelvis are stretched muscular lamellæ and tendinous aponeuroses, the *cingulum abdominis musculoso-aponeuroticum* of Albinus and Haller, which, with integument, cellular membrane, &c. form the anterior, lateral, and for the most part the posterior walls of the abdomen, and circumscribe that space to which we have already alluded under the name of the cavity of the abdomen.

The superior wall of the abdomen is the diaphragm, and the inferior wall of the abdomen, strictly so called, is formed by the ilia and their muscles, and is open in the centre at the superior outlet of the pelvis; but if the abdominal and pelvic cavities be considered as one, then those parts which fill up the inferior outlet of the latter must be considered as likewise constituting the inferior wall of the former.

In the male adult the abdomen presents an expanded convex surface anteriorly (the anterior wall or *proper abdominal region);* posteriorly a broad surface not so extensive, situated between the last ribs and the superior margin of the pelvis, and divided into two by the lumbar portion of the spine (the posterior wall, the loins, or *lumbar regions.)* The anterior and posterior walls are connected with each other on the sides by two narrow regions (the lateral walls or the flanks.)

The outline of the anterior wall or proper abdominal region constitutes an oval, whose long axis is vertical. The surface is generally more or less convex during life, proportionally with the degree of embonpoint of the individual, and also according to the condition of the diaphragm. After death, excepting in very fat subjects, or where the intestines or peritoneal cavity are much distended from any cause, this surface is in a variable degree collapsed, and more or less concave, but especially so in very thin and emaciated subjects. There is a constant adaptation in the condition of this surface to that of the abdominal viscera, so that the practitioner can in general argue pretty accurately, from the state of the abdominal surface, respecting that of the abdominal viscera, except in cases where every thing is masked by a superabundant deposition of adipose substance. So close is the apposition of the abdominal wall to the surfaces of the subjacent viscera, that in some cases of extreme emaciation the peristaltic movement of the intestinal canal is manifested by the successive elevation and depression of small portions of the walls corresponding to the dilated and contracted portions of intestine. This surface is divided into two equal and symmetrical portions by a groove which exists along the middle line, and which is chiefly apparent in the two superior thirds. This groove commences below the ensiform cartilage, where there is a slight depression, denominated the *scrobiculus cordis,* (creux de l'estomac.) In this line, about midway between the pubis and xiphoid cartilage, is the round depression called the *umbilicus* or navel. Just over the pubis there is a prominent surface in both sexes covered



with hair; in the female it is much more prominent than in the male, and is called the *mons Veneris*. In subjects where the muscular system is well developed, there exists on each side of this median groove an oblong convexity, extending from the anterior surface of the lower part of the chest to the pubis; these convexities indicate the situation of the *recti* muscles. In statues representing athletic men, the prominences occasioned by these muscles are generally very well shewn, and are divided by transverse superficial digressions into small quadrilateral portions, generally three in number. External to these prominences there is, in similar muscular subjects, a fissure extending from the border of the chest, in a slightly curved course with external convexity, to a point a little to the inner side of the anterior superior spine of the ilium; this fissure has internal to it the prominence from the recti muscles, and external that from the broad muscles of the abdomen. Gerdy calls it the lateral groove or furrow of the abdomen.* (See *fig.* 1.)

The posterior wall or the region of the loins, *(lumbar region,)* is in every way of less extent than the anterior. Its vertical height is equal to the distance between the last rib and the margin of the ilium. It is continuous on the sides with the flanks, and is divided along the middle line by a groove, corresponding to the lumbar spinous processes, into two symmetrical portions, each of which forms a large and prominent relief. Each relief corresponds to a great muscular mass, which almost wholly occupies this region, and its prominence is greatest when those muscles are in a state of contraction, as during the erect posture. Each relief is concave from above downwards, and in a degree directly proportionate to the contrac-

* Gerdy, Anatomie des Formes Extérieures, p.189. The above engraving is reduced from the folio plates which accompany this work.

tion of the muscles, insomuch that in some individuals the concavity is habitually very considerable, as in those who carry burdens on the head or in front of the body, in pregnant women, &c. (See *fig.* 2.)

The limit of this wall on each side is indicated by a groove or fissure which passes obliquely upwards and outwards towards the ribs, and corresponds to the outer margin of each relief, or that of the lumbar muscles; these lines also indicate the posterior limits of the lateral walls of the abdomen, or the flanks. Anteriorly the flank of each side is continuous with the anterior wall of the abdomen; above it is limited by the margin of the thorax, and below by the margin or crest of the ilium. It is concave on its surface from above downwards, (except in cases of great embonpoint, where the concavity is obliterated,) and convex from before backwards. Gerdy remarks that in subjects in which the muscles have a considerable development, a relief is formed just above the crista ilii by the broad muscles of the abdomen at their insertion into this osseous border. Upon antique statues this relief is in general made too prominent.

The anterior or proper abdominal region has been subdivided into smaller compartments, with a view to facilitating descriptions, pathological or otherwise. This subdivision is completely arbitrary, and therefore some differences will be found among the various anatomical authors as to the precise limits of each region. That which is here subjoined, however, appears to be pretty generally agreed upon in this country. Lines connecting particular points drawn upon the surface, mark out these subdivisions, and if planes be supposed to be carried from these lines horizontally backwards to the posterior wall, the cavity of the abdomen will thus be divided into segments, each of which has its particular portion of the abdominal viscera. It is an instructive exercise for the student to practise himself in examining the particular viscera which correspond to particular regions. We are thus enabled, as Blandin has remarked,* to resolve the problem, "a point of the surface of the abdomen being wounded deeply in a given direction, to determine what organs have been injured; and reciprocrally, an organ having been wounded in a particular part of the abdominal cavity by a sharp instrument, which entered in a given direction, to determine what part of the abdominal walls must necessarily have been injured."†

The limits of these several regions or compartments may be thus indicated:‡ let a line be drawn horizontally from the extremity of the last rib on one side to the same point on the other, and let another line parallel to the preceding be drawn between the two anterior superior spinous processes of the ilium: the abdominal surface is thus divided into three great regions, each of which is subdivided into three by means of a vertical line let fall on each side from the anterior extremity of the seventh or eighth rib to a point a little external to the spine of the pubis. Nine regions are thus marked out, the relations and boundaries of which may be described as follows.

* Anatomie Topographique, p. 423.

† The division of the surface of the abdomen into regions is as old as Aristotle.

‡ See an engraving exhibiting these subdivisions, in the article Abdomen of the Cyclopædia of Practical Medicine.

The superior region, or that above the first horizontal line, is the *Epigastrium*, which name it derives from its close relation to the stomach; (επι, upon, over; γαστηρ, the stomach.) The epigastrium is bounded superiorly and laterally by the margin of the thorax, and its inferior limit is indicated by the transverse line. The vertical lines subdivide it into two lateral regions, each of which is bounded immediately above by the lower margin of the thorax, beneath which these regions extend in a direction upwards and backwards: they are hence called hypochondria (υπο, under, χονδρος, cartilage). Between the hypochondria, is the proper *epigastric region*, which at its superior part and just below the xiphoid cartilage presents the depression already alluded to under the name of scrobiculus cordis (scrobiculus, the diminutive of *scrobs*, a depression).

Immediately below the epigastrium, and separated from it by the superior horizontal line, is the *umbilical* region, which has its name from the presence of the umbilicus in it. This region is limited above and below by the two horizontal lines, and is subdivided by the intersection of the two vertical lines into three regions: the lateral ones are the *lumbar* regions, so called from their correspondence with those portions of the posterior abdominal wall which bear the same name; and the middle one is the *proper umbilical* region.

Between the inferior horizontal line and the margin of the pelvis, is the *hypogastrium*, (υπο, beneath, γαστηρ, the stomach). This region is limited below in the centre by the pubis, and on each side it communicates with the upper part of the thigh. It is subdivided into the *iliac* regions on each side, and the proper hypogastric or *pubic* region in the centre. The two former constitute the upper or abdominal portion of the great region of the groin, which is completed inferiorly by the upper part of the anterior surface of the thigh. These regions afford peculiar interest to the surgical anatomist, in consequence of the occurrence in them of the most common forms of hernia.* (See Groin, Region of the.)

The structures which enter into the composition of the abdominal parietes, or their elements, (as the term has been lately applied,) are—1. the skin: 2. the subcutaneous tissue or superficial fascia: 3. muscles and their aponeurotic expansions: 4. a particular fibrous expansion, or fascia: 5. a thin and filamentous cellular tissue, which separates the fascia just named from the sixth element: 6. the peritoneum, which, however, is not to be found in the composition of all the walls of the abdomen.

* Velpeau applies the term *zone* to the primary regions included between the horizontal lines.—Anat. Chirurg. t. ii.

In and between these several structures ramify the various arteries, veins, lymphatics, and nerves, which constitute the vascular and nervous supply to the abdominal parietes.

1. The skin on the anterior and lateral parts of the abdomen is thin and smooth, and in some parts covered with hairs, as along the middle line, especially below the umbilicus and over the pubic region. Along the median line the cutaneous follicles are largely developed, and during pregnancy an increased secretion of pigmentum is said to take place, producing a brownish colour of the skin in these regions. In women who have borne children, the skin becomes wrinkled to a considerable degree, and the epidermis exhibits, as Winslow has remarked, a great number of lozenge-shaped spaces disposed in a reticular manner.*

In the epigastric region the skin is much more sensitive during life than in the other parts of the abdomen, and with some persons sympathizes with the stomach in a remarkable degree, so that pressure on it even in the healthy state produces a degree of pain or uneasiness in that organ, or even a tendency to nausea. In the umbilical region we observe a depression, the floor of which is more or less elevated in the centre. This depression is denominated the navel or *umbilicus*, (the diminutive of *umbo*, a nob or button.) It is produced by the firm adhesion of the skin to the subjacent structures, its true nature being that of a cicatrix, occupying the site of a former perforation through which the umbilical arteries and veins and the urachus passed in maintaining the circulation between the fœtus and placenta. In very fat persons, the depth of the depression is often very much increased by reason of the great thickness of the abdominal parietes, and in some instances its form assumes that of a slit, and sometimes, instead of a depression, there is a greater or less prominence of the integument.

In the lumbar region the skin is thicker and firmer than in the others; and we generally find it in a state of congestion after death, in consequence of the position of the body.

2. The subcutaneous cellular tissue on the anterior surface of the abdomen has obtained especial attention from anatomists, particularly that portion of it which is found in the hypogastric regions. It is denominated *the superficial fascia*,† and is merely an expanse of cellular tissue possessing the same general characters as that which is found in all other parts of the body; it is continued upwards over the thorax, laterally into the region of the back, inferiorly along the thighs, and into the scrotum. It varies in thickness according to the quantity of fat which is deposited in its cells;* in some instances it has been known to possess a thickness of three inches. Thin but muscular subjects afford the best examples from which to study the superfical fascia of the abdomen: in such subjects we find it in general of a much denser character than in others, very strong and elastic and easily divisible into laminæ, produced, no doubt, by the pressure which it experiences from the weight of the abdominal viscera, and the constant attrition occasioned by the action of the abdominal muscles. In the iliac region, immediately above Poupart's ligament, the density of this fascia is most conspicuous. Here some have regarded it as a fibro-cellular membrane; but the opaque bands which give it a fibrous appearance are merely the walls of the membranous cells rendered thicker and denser than they are in other parts. I cannot agree with Beclard† that it presents almost all the characters of an aponeurosis, inasmuch as it differs from an aponeurosis in wanting the shining and regular surface, and in possessing a degree of elasticity which never belongs to aponeurotic expansions. The elasticity of the superficial fascia is remarkable, and is by some compared to the elastic expansion over the abdomen of the larger quadrupeds;‡ the comparison, however, is inaccurate, inasmuch as they are two distinct tissues, the former being cellular, and the latter the aponeurosis of the oblique muscles, which in some degree partakes of the properties of the yellow elastic fibrous tissue *(tissu jaune)*.

Inferiorly the superficial fascia moves freely over Poupart's ligament, and is continued over the thigh (see GROIN, REGION OF THE). Along the middle line it is very adherent to the subjacent aponeurotic structure (the linea alba) as well as to the skin,—a fact which may be remarked of the subcutaneous cellular tissue in other parts of the body, and which was long ago noticed by Bordeu, when he observed that the cellular tissue is constricted *(etranglée)* in all its median portion, and that its cells *(ballons ou pouches)* are closed over the axis of the body. When this superficial fascia is dissected off, a very thin layer of cellular membrane, perfectly diaphanous, is found to adhere to the subjacent aponeurotic expansion. This will be found particularly adherent over Poupart's ligament, and is that which is referred to by some anatomists (as Manec, Cloquet, &c.,) as a deep *process* of the superficial fascia which adheres to Poupart's ligament, and so forms a superficial septum between the abdomen and thigh. To see this layer the superficial lamina should be raised by commencing the dissection of it

* Winslow's Anatomy, by Douglas, v. ii. p. 160.

† The application of the term *fascia* to the subcutaneous cellular investment in various parts of the body has occasioned no small degree of confusion among anatomists. A singular degree of confusion exists in Velpeau's description of this fascia: he observes in one place that the deep layers of the subcutaneous cellular tissue constitute the superficial fascia, and in the next page states that "the superficial fascia is nothing else than the cellular tissue condensed, whose laminæ strongly applied one against the other, are ultimately reduced to somewhat of the aponeurotic form." I shall adhere to this latter definition, and consider *superficial fascia* as synonymous with *subcutaneous cellular tissue*.—Velpeau Anat. Chirurg. vol. ii. p. 4 and 5.

* Cloquet says it is, as it were, decomposed by the deposition of fat.—Recherches Anat. sur les Hernies de l'Abdomen, p. 11.

† Dict. de Médecine, art. *abdomen*.

‡ *Vid. Blandin, Anat. Topog.*

below and carrying it upwards; the expansion will then appear to arise from Poupart's ligament, and spread over the subjacent aponeurosis. In some subjects it is so thin as to appear to be little more than the proper cellular covering of the muscle and its aponeurosis, but in others it assumes a considerable degree of density. It may be called the deep layer of the superficial fascia; it deserves attention from the fact that the femoral hernia, in its ascent on the abdomen, lies between it and the superficial layer. It is to this fascia that Scarpa must allude under the name of "aponeurotic web of the muscle of the fascia lata," and hence some have called it Scarpa's fascia.* The whole of the superficial fascia has been called Camper's fascia, because it was first fully described by that writer.†

On the posterior wall of the abdomen, in the lumbar regions, the cellular tissue is more abundant and more lax; here we frequently find it infiltrated with serous fluid, in consequence of the usual supine posture of the body after death. It is continuous above with the subcutaneous tissue in the dorsal region, and below with that in the glutæal regions. It, too, is firmly adherent along the middle line to the lumbar spine anteriorly, and to the skin posteriorly.

3. *Muscles and aponeuroses.*—The abdominal parietes owe their thickness chiefly to the muscular lamellæ and the aponeurotic expansions, which enter into their composition. In the anterior and lateral walls we find on each side five pairs of muscles, of which four are constantly present. These are, 1, M. obliquus externus; 2, obliquus internus; 3, transversalis; 4, rectus abdominis; 5, pyramidalis, which last is frequently absent.

1. *Obliquus externus. (Obliquus descendens; costo-abdominal; ilio-pubi-costo-abdominal.)*

When the superficial fascia covering the anterior and lateral surfaces of the abdomen has been dissected away, this muscle is brought into view. It consists of a flat muscular portion, situated superiorly and posteriorly, and of a tendinous or aponeurotic lamella anteriorly and inferiorly, but which is largest and strongest in the latter situation.

The muscular portion of the external oblique is attached by separate fasciculi to the external surfaces of the eight inferior ribs, from the fifth to the twelfth inclusive. These fasciculi indigitate at their attachment with similar ones, of the serratus magnus, from the fifth to the ninth inclusive, and of the latissimus dorsi from the tenth to the twelfth. From these points of attachment, described by most English anatomists as the origin of the muscle, the fibres pass obliquely downwards and forwards, with different degrees of obliquity, the middle fibres being the most oblique; the superior taking a direction nearly horizontally inwards, and the posterior ones passing nearly vertically downwards. The anterior and middle fibres are inserted into the outer convex border of the aponeurotic lamella of the muscle, but the posterior are inserted into the outer lip of the two anterior thirds of the crista of the ilium by short tendinous fibres. The fibres of this muscle vary considerably in length, those which are highest up being the shortest, the middle ones the longest, and next in length the posterior fibres. The aponeurotic lamella of the external oblique muscle is found on the anterior part of the abdomen, both superiorly and inferiorly. In the former situation the aponeurosis is extremely thin and weak; it is transparent, so that the upper extremity of the rectus muscle which it covers is visible through it. This, too, is the narrowest portion of the aponeurosis, which increases in breadth, strength, and thickness as it descends. The aponeurosis, like the muscular portion, consists of a series of fibres, for the most part inclined obliquely downwards and inwards, excepting the superior ones, whose direction is horizontal. At several places these fibres are separated from each other so as to allow the subjacent muscle to be seen through the interval. At various parts the tendon is perforated by vascular apertures, which are occasionally so enlarged as to admit little peritoneal prolongations to pass through them. Along the middle line, from the ensiform cartilage to the symphysis pubis, the aponeurosis forms an interlacement with its fellow of the opposite side, and this interlacement with that of the subjacent aponeuroses constitutes the tendinous line called *linea alba*, which, as Velpeau observes, may be regarded as the centre in which all the fibrous elements of the abdomen terminate. Just above the symphysis pubis, the decussating fibres are not intermixed in the same manner as in other parts of the linea alba: there the bundle of one side crosses anteriorly or posteriorly to that of the other, without any union of fibres, to be inserted into the pubis of the side opposite to that from which it came.

A little above and external to the pubis, a separation of the fibres of the tendon of the obliquus externus takes place, leaving an opening which is denominated *the external abdominal ring*, through which the rounded bundle composed of the spermatic vessels and duct *(the spermatic cord)* passes in the male, and the round ligament of the uterus in the female. The aponeurotic fibres which form the immediate boundaries of this opening are termed the pillars of the ring, of which one is superior, internal, and anterior, the other is inferior, external, and posterior, and passes behind the cord. External and inferior to this opening, we observe that the aponeurosis of the external oblique muscle is extended from the pubis to the anterior superior spine of the ilium. On the pubic side, the fibres, which are the same that form the inferior pillar of the ring, are inserted into the spine of the pubis, and being

* Vid. Scarpa on Hernia, by Wishart, p. 22; also Todd on Hernia, Dub. Hosp. Reports, vol. i. p. 246; and Flood's plates of Inguinal and Femoral Hernia.

‡ Camper, Icones Herniarum, p. 11.

reflected backwards, outwards, and a little upwards, they are likewise inserted into the linea ilio-pectinea, which commences at the spine of the pubis. The lower margin of the tendon is thus folded back a little as it arches over the excavation between the pubis and ilium, so as to present towards the abdomen a slight channel-like excavation, which affords origin to the muscular fibres of the internal oblique as well as to those of the transversalis, whilst it has the appearance of a rounded ligamentous cord towards the thigh. In this manner is formed *Poupart's ligament*, which, contrary to what its usual name denotes, is not a distinct ligamentous cord, but the inferior margin of the external oblique stretched from pubis to ilium, and folded a little upon itself. By its superior margin it is continuous with the fibres of the tendon of the external oblique, which fall obliquely upon it; by its inferior margin it is intimately connected with the fascia lata of the thigh; externally it is inserted into the anterior superior spine of the ilium; and by its pubic extremity it has three attachments, 1. to the body of the pubis; 2. to the spine of the same; and 3. to the linea ilio-pectinea, constituting what has been called *Gimbernat's ligament*, which has a sharp slightly crescentic margin directed backwards and outwards towards the femoral vessels.* (See Groin, Region of the.)

The external abdominal ring is a triangular opening, situated obliquely; the superior angle being directed upwards and outwards, and its base, represented by a line uniting the pubic insertions of the two pillars, resting upon the pubis. The superior angle is formed evidently by the separation of the fibres of the aponeurosis, the primitive direction of which is the same as that of a perpendicular from the apex to the base of the triangle, viz. downwards and inwards, (sacrad and pubad.) This separation, however, is strengthened, and the angle rounded by some tendinous fibres which intersect the oblique ones nearly at a right angle, arising as a cord of variable thickness from Poupart's ligament, and passing upwards and inwards over the apex of the ring, gradually separating into several tendinous fibres. These fibres are sometimes very strong, at other times very feeble and scarcely perceptible; but it rarely, if ever, happens that they are completely absent; they have been termed *intercolumnal bands*. I have seen them so strong that they could be distinctly dissected off the external oblique aponeurosis, like a separate tendinous expansion; but most frequently they are so united to the aponeurosis as to render it impossible to remove them without injury to it. These fibres are evidently intended, as Scarpa expresses it, "to fix the limits of the inguinal ring, and to oppose the further divergence of the tendinous pillars towards the side." They are equally met with, although not nearly so much developed, in women and children as in men; and Mr. Lawrence asserts that in old herniæ they are particularly strong. I cannot confirm this remark from my own observation, as in my dissections of old herniæ, I have not found them particularly developed; nor is it consistent with the general result of pressure from within on *tendinous* fibres to believe that such pressure would produce an increase of development in them.

The size of the external abdominal ring is greatest in the male subject, but here it varies considerably, sometimes closely embracing the cord as it passes through it, and at others appearing much too large for it. In the male the parts which pass through it are the spermatic cord, enveloped in its proper tunic, and in one of condensed cellular membrane prolonged from the fascia transversalis, a branch of the genito-crural nerve, the cremaster muscle, the cremasteric artery, and the spermaticus superficialis nerve. In the female, we find the round ligament of the uterus, covered and accompanied by similar parts, excepting the cremaster. From the margin of the external abdominal ring, a cellular expansion or fascia is carried over the cord or round ligament, and has been denominated *fascia spermatica*. This fascia consequently forms a covering of any hernia that may be protruded through the external ring; and, accordingly, in old herniæ we find it greatly thickened. Its formation is simply in accordance with what we find occurring in all parts of the body, viz. that when any part passes through an opening in a fibrous membrane, it carries with it a cellular expansion from the margin of that opening. This we observe in the passage of the vena cava through the diaphragm, of the urethra through the triangular ligament or deep perineal fascia. This view confirms the opinion of Sir A. Cooper, that this fascia is a production from the margin of the ring itself.

The external oblique muscle is covered in all its extent by the superficial fascia; its costal margin is related to the serratus magnus, and to the latissimus dorsi, with which muscle it is also in close relation by its posterior margin, being sometimes slightly overlapped by the anterior margin of the latissimus, but at others separated from that muscle by a triangular interval through which the fibres of the obliquus internus appear: inferiorly the fascia lata of the thigh is related to the margin of the external oblique muscle, both as it covers the glutæi, and as it lies in front of the thigh. Along the middle line the aponeuroses of opposite sides meet at the linea alba, and superiorly the muscular fibres are related to and sometimes connected by a fleshy slip with those of the pectoralis major, and the aponeurosis is continuous with that of the same muscle.* When the ex-

* The terms *crural arch*, and *ligament of Fallopius*, are also used synonymously with Poupart's ligament. Velpeau calls it *bandelette ilio-pubienne du grand oblique*.

* "By its position, the direction of its fibres, and the short distance to which its fleshy portion extends forwards, the external oblique corresponds so much to the external intercostals, that one is led to say that it represents them in the abdomen."—*Meckel*.

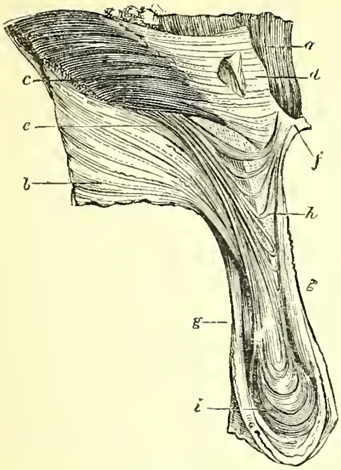
ternal oblique is removed from its osseous attachments, and raised inwards, it is found to cover the internal oblique, with part of the tendon of which it is ultimately united as the two tendons approach the linea alba.

2. *Obliquus internus (obliquus ascendens, ilio-abdominal, ilio-lumbo-costi-abdominal)* is smaller than the preceding muscle, which it resembles in shape and general characters. The direction of its fibres, however, is opposite, inasmuch as the fibres of the two muscles decussate with each other, thus adding considerably to the strength of the abdominal wall, and forming a great protection against visceral protrusions. The external attachments (or, as systematic writers call it, the origin of the muscle) is 1. by short fleshy fibres to the tendinous expansion covering the lumbar mass of muscles, called *fascia lumborum*, which is formed by the posterior lamina of the tendon of the transversalis abdominis: 2. to the two anterior thirds of the middle portion of the crista ilii, between the external oblique and the transversalis as far forwards as the anterior superior spine: 3. to the groove in the upper or abdominal surface of Poupart's ligament for about its external third. The superior fibres pass upwards and inwards, and are inserted by fleshy slips into the cartilages of the twelfth, eleventh, and tenth ribs, in the intervals between which they are either separated from the intercostal muscles by a fibrous intersection, or confounded with them, and by a tendinous aponeurosis into the cartilages of the ninth, eighth, and seventh ribs as well as into the xiphoid cartilage. Lower down, the fibres which arise from the crista ilii, as well as those from Poupart's ligament, pass inwards, the superior obliquely upwards and inwards, the inferior more horizontally, and the lowest fibres inclining a little downwards, and are all inserted, like those of the *obliquus externus* into the outer convex margin of an aponeurotic expansion, which goes to be inserted along the middle line. This tendon passes inwards for a short distance, nearly as far as the outer margin of the rectus muscle, as a single lamina. Along this margin, and as low down as the inferior fourth of the rectus muscle, the tendon divides into two laminæ, of which the anterior adheres to the posterior surface of the tendon of the external oblique, and the posterior to the subjacent tendon of the transversalis, both laminæ going to be inserted into the ensiform cartilage and linea alba, the one in front, the other behind, the rectus muscle. (See *fig.* 4, *a.*) For a distance, however, corresponding to the inferior fourth of the rectus muscle, the tendon of the obliquus internus remains undivided, and does not adhere to that of the obliquus externus. It, however, is united, although not inseparably, to the tendon of the transversalis, and both go in front of the rectus to be inserted into the linea alba and pubis: these tendons are here called by some *the conjoined tendons*. Along the line at which the tendon of the *obliquus internus* divides into two laminæ, the aponeurosis of the obliquus externus and that of the transversalis adhere to it more closely than they do externally to that line, and thus a thickened portion of the abdominal aponeurosis is formed, taking the course of the outer margin of the rectus muscle: this line is called the *linea semilunaris*, and is that in which the operation of *paracentesis abdominis* used formerly to be practised.

The inferior margin of the obliquus internus is deserving of particular attention. The inferior fibres attached to the external third of Poupart's ligament in the groove formed in it pass transversely inwards and parallel to the ligament, crossing over the spermatic cord, to be inserted into the pubis. Here the muscle is confounded with the inferior fibres of the subjacent one, the transversalis; so that it is not only difficult to say which muscle passes lowest down, but it is difficult, and often impossible, to separate the two muscles. Hence the lower margins of the fleshy fibres as well as of the aponeuroses of these two muscles are constantly spoken of conjointly; however, I have several times succeeded in separating them distinctly, and I am decidedly of opinion that the aponeurosis of the *obliquus* internus seldom or never descends so low down as that of the transversalis. The lowest of the fibres of the obliquus internus are sometimes observed to separate a little from the others, so as, instead of a directly transverse, to assume a course slightly curved with the concavity upwards and a little outwards, lying in front of the cord; in some cases fibres of this kind are observed to lie in front of the spermatic cord, and to descend much lower down, taking of course a much more curved direction, still attached on the outside to Poupart's ligament, and on the inside to the pubis, so that a series of curved fibres are thus found to adhere to the anterior surface of the cord and of the tunica vaginalis, exhibiting an equal number of reversed arches. But this disposition is rarely seen in its most highly developed state, excepting where some tumour has been connected with the cord or testicle, as hernia, hydrocele, &c.

This arched arrangement of muscular fibres in connection with the spermatic cord and tunica vaginalis testis constitutes *the Cremaster muscle* (*κρεμαω, suspendo*,) the great tenuity of which in the natural state of the parts has rendered it difficult to determine its precise attachments, and consequently has given rise to the great discrepancy which is observable between the descriptions of different writers. When this muscle is examined in a case of old hernia or hydrocele, it is found, as Scarpa originally described it, to consist of two bundles; the first, external to the cord which arises from Poupart's ligament along with the internal oblique, follows the course of the spermatic cord, which it accompanies through the external abdominal ring, sending at intervals fibres arching in front of the cord to join a similar bundle on the inner side, as may be seen in the accompanying engraving from a plate in Sir A. Cooper's work on the testis (*fig.* 3). Inferiorly, this bundle, a

Fig. 3.



c, the internal oblique; *e*, the descending fibres; *f*, point of insertion into the pubis; *h*, one of the reversed arches; *d*, conjoined tendons; *a*, rectus muscle.

good deal diminished in size, crosses over the inferior and anterior portion of the tunica vaginalis testis, and begins to ascend along the inner side of the testicle and cord, keeping more posteriorly: this constitutes the second bundle; it gradually increases in size as it ascends by receiving the transverse fibres from the bundle of the opposite side, and it is inserted, sometimes by a distinct tendon, into the pubis near its spine. In some cases I have totally failed, even after the most careful dissection, in detecting a continuity by *muscular* fibre between these two bundles, insomuch as to lead me to imagine that they may be connected by a very condensed cellular tissue or thin aponeurotic lamella after the manner of the digastric muscles. In general the external bundle is larger than the internal, but Cloquet has seen the reverse three times; and on referring to my notes, I find I have seen two instances in which the internal bundle exceeded the external in size.

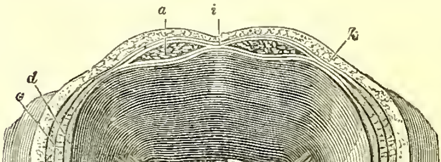
Many anatomists have noticed only the external bundle of the cremaster, and altogether overlooked its reversed arches, which is not to be wondered at when we remember that even where the lateral bundles are strong and well developed, the arched fibres are sometimes pale and thin. However, the description now given is pretty generally admitted as the true one, and is sanctioned by such observers as Scarpa, Cloquet, Cooper, Velpeau, and I may add that I have seen this arrangement in cases where both testicle and cord were healthy. It would appear that its formation is effected by the testicle in its descent, for before that takes place the muscle does not exist; at least such is the result of Cloquet's observations on a considerable number of fœtuses before, during, and after the descent of this organ. Before the descent the *gubernaculum testis* occupies the inguinal canal, and is covered by the fibres of the internal oblique, which adhere to it: when the gubernaculum is drawn down, these fibres descend with it, forming a series of reversed arches.

In some female subjects we see an arrangement of the inferior fibres of the internal oblique as they cross over the round ligament, which resemble a rudimentary state of the cremaster muscle.

A thin layer of cellular tissue, sometimes containing a small quantity of fat, is interposed between the anterior surface of the obliquus internus and the obliquus externus. At the inferior edge of the obliquus internus the spermatic cord is seen emerging from the abdomen and passing obliquely inwards and a little downwards to the external abdominal ring. Here it lies in a groove or channel, called *the inguinal canal,* which extends from the point at which the spermatic cord emerges from the abdomen, (the opening in the fascia transversalis called internal abdominal ring) to the external abdominal ring. This canal is bounded or covered anteriorly by the tendon of the obliquus externus; posteriorly by the fascia transversalis and some fibres of the tendon of the transversalis muscle towards the inner side; superiorly by the margin of the obliquus internus and transversalis muscles; and inferiorly by the groove of Poupart's ligament.* (A full description of this canal will be found in the article Groin, Region of the.)

3. *Transversalis (lumbo-abdominal, lumbo-ili-abdominal).* This muscle is immediately under cover of the obliquus internus; its name is derived from the transverse direction of its fibres. In its general character it resembles the obliqui, being like them a muscular lamella, inserted into a tendinous expansion, which again is inserted into the linea alba. Superiorly the fleshy fibres of this muscle are attached by distinct bundles to the internal surface of the cartilages of the ribs forming the lower margin of the thorax, where these bundles indigitate with those of the diaphragm: 2dly, in the interval between the last rib and the crista

Fig. 4.



* "The *obliquus internus* corresponds to the internal intercostals by the direction of its fibres, by its being situated under cover of the *obliquus externus*, and because its fleshy fibres extend much further forwards than those of the last-named muscle."—*Meckel.*

ilii, the fibres arise from a tendinous lamella, which itself is trifoliate in its origin. This tendon is found as an undivided lamella between the outer margin of the quadratus lamborum and the commencement of the fleshy fibres of the muscle, extending vertically from the last rib to the crista ilii. *(Fig. 4, l.)* The three laminæ of which this tendon is composed arise from different portions of the vertebræ in the lumbar region of the spine; the posterior, which is thick and strong, and is commonly called *fascia lumborum*, arises from the extremities of the spinous processes, and covers the lumbar mass of muscles. *(Fig. 4, g.)* The middle, which is weak, is attached to the apices of the transverse processes; it lies in front of the lumbar mass and behind the quadratus lumborum *(fig. 4, h)*; and the anterior arises from the pedicles which connect the transverse proeesses to the bodies of the vertebræ, and covers the quadratus lumborum muscle in front *(fig. 4, f)*. Inferiorly, the transversalis muscle attaches itself to the inner lip of the crista ilii for its three anterior fourths, and to the external third or half of Poupart's ligament, corresponding to the attachments of the obliquus internus. The fleshy fibres of the muscle pass from these several points of attachment transversely inwards, the middle being the longest, and the superior the shortest, and are inserted into the outer convex margin* of a tendinous aponeurosis, which extends to the linea alba. This aponeurosis is intimately connected with the posterior division of that of the obliquus internus for an extent corresponding to the three superior fourths of the rectus muscle, behind which both pass to be inserted into the ensiform cartilage and linea alba, *(fig. 4, a,)* forming the posterior wall of the sheath of the rectus. Inferiorly, as we have already remarked, these conjoined tendons go together in front of the rectus, and are inserted into the inferior fourth of the linea alba and into the pubis. At the inner extremity of the inguinal canal, it will be seen by carefully raising up the spermatic cord, that this union of the tendons of these two muscles ceases, and we can trace the fibres of the transversalis tendon passing down in a curved direction, more curved as they are more external, and insinuating themselves behind the cord to be inserted into Gimbernat's and Poupart's ligament for about its external third or fourth. This mode of insertion of the transversalis tendon was first described by Sir Astley Cooper,† and these fibres were by him called the *folded fibres* of the transversalis. They adhere to the subjacent fascia, (fascia transversalis,) and add to the strength of the inner portion of the posterior wall of the inguinal canal. They correspond, in a great measure, to the external abdominal ring, and may be counted as one of the obstacles provided against the direct descent of a hernia.

Such is unquestionably the usual mode of insertion of the tendon of the transversalis muscle; but Mr. Guthrie has lately called the attention of anatomists to a variety which it is important to know, although it cannot be of frequent occurrence. In this variety the spermatic cord appears to pass through a slit in the inferior margin of the transversalis muscle, so that a bundle of muscle passes behind as well as before the cord; the posterior one ending in tendinous fibres, which, like the folded fibres above described, are inserted into Poupart's ligament.* It is very generally believed that the inferior fibres of this muscle contribute, as well as those of the obliquus internus, to form the cremaster. The two muscles are so closely connected externally by their inferior margins, that it is natural to suppose that both do send fibres to the cremaster. Sir Astley Cooper expresses the relation of the cremaster to these two muscles in the clearest way, when he says that it arises from Poupart's ligament within the inguinal canal, and there *blends* with some of the fibres of both these muscles.†

A thin layer of cellular tissue covers the transversalis muscle, and separates it from the obliquus internus. At its superior margin it is intimately related to the diaphragm, and some of its fibres seem to be continuous with it: posteriorly, by the triple partition of its tendon, it ensheaths the lumbar muscles, and it lies upon the fascia transversalis, which, with a layer of cellular tissue, separates it from the peritoneum.‡

4. *Rectus abdominis (sterno-pubien).* After the superficial fascia has been removed so as to expose the aponeurosis of the external oblique, the recti muscles are seen on either side of the middle line covered by this aponeurosis, which it is necessary to slit up in order to expose the muscles. The rectus owes its name to the perpendicular course of its fibres, which pass from the pubis to the thorax, nearly parallel to the middle line. It is long and narrow; however, its breadth increases as it advances upwards, and as it increases in breadth it diminishes in thickness. At the pubis the muscle has its most fixed point of attachment, whence it is generally said to have its origin there: it arises by a short tendon from the symphysis of the pubis; this tendon is very narrow at its origin, but soon expands, and unites with the muscular fibres, which pass vertically upwards to the lower margin of the thorax, where the muscle is considerably increased in breadth, and divides into three portions; the first or internal one is inserted into the costoxiphoid ligament and cartilage of the seventh rib; the middle, larger than the preceding, into the cartilage of the sixth rib at its inferior edge and anterior surface;

* This margin forms the *linea semilunaris* of Spigelius.

† Cooper on the Testicle, p. 35.

* Guthrie on Inguinal and Femoral Hernia, pp. 11, 12, 13, 4to. Lond. 1833.

† Op. cit. p. 38.

‡ "The *transversalis* corresponds, by the direction of its fibres, to the '*triangularis sterni*;' also, by its situation, by the attachment of its external edge to the internal surface of the ribs, and by that of its internal edge to the sternum and linea alba."—*Meckel.*

and the external, the largest of the three, into the inferior edge of the cartilage of the fifth rib. This muscle is remarkable for its tendinous intersections, which cut the fibres at right angles, and are called *lineæ transversæ*;* they vary in number from three to five, and are always more numerous above than below the umbilicus. In general there is one on a level with the umbilicus; the superior one being about an inch below the superior attachment of the muscle, and a third midway between these two: when a fourth and a fifth exist, they are below the umbilicus. They adhere to the anterior wall of the sheath closely, and but very slightly or not at all to the posterior. Sometimes the intersection does not go completely through the thickness of the muscle so as to appear on its posterior surface, and thus the posterior fibres are longer than the anterior; but as Bichat remarks, it never happens that any of the muscular fibres pass from one extremity of the muscle to the other without uniting at least one of these intersections. Sometimes, too, the intersection does not go through the breadth of the muscle, and this is generally the case with that below the umbilicus. The effect of these intersections is to convert the muscle into so many distinct bellies, each of which has its proper action, and is, as Beclard asserts, provided with a separate nerve.†

The rectus muscle is enveloped in a fibrous sheath, the mode of formation of which the reader must have collected from the description of the oblique muscles. The anterior wall of this sheath is formed by the aponeurosis of the external oblique alone over the chest, and by the same aponeurosis and the anterior layer of that of the internal oblique, from the xiphoid cartilage to the inferior fourth of the muscle; (both which aponeuroses over the internal half of the muscle are so adherent to each other as to form but one lamina;) and in its inferior fourth by the conjoined aponeuroses of the two obliqui and transversalis.

The posterior wall of the sheath is deficient superiorly where the muscle covers the cartilages of the ribs with which it is in contact, and inferiorly for a space corresponding to the inferior fourth of the muscle. So much of it as exists is formed by the tendon of the transversalis and the posterior lamina of that of the internal oblique, so that the rectus appears to have passed at its inferior extremity through a transverse slit in these conjoined tendons, so as to get between them and the peritoneum.

The rectus muscle covers, at its superior extremity, the cartilages of the two last true ribs and a part of those of the two first false, and also the xiphoid appendix. The internal mammary and epigastric arteries are found behind it in the sheath.

Between the recti muscles is the fibrous cord called *linea alba*, produced by the interlacement of the aponeuroses of the opposite sides, noted in surgery as being in its inferior half the seat of the operations of paracentesis abdominis, paracentesis vesicæ supra pubem, the suprapubic lithotomy, and the Cæsarean operation. This cord extends from the xiphoid cartilage to the symphysis pubis, with the anterior ligament of which articulation it is identified. It does not present the same breadth in its whole course, being broader in the umbilical region than elsewhere. In this region we find in the linea alba the perforation which gave passage to the umbilical vessels in the fœtus and the urachus, and through which the fibrous remains of those vessels pass to be inserted into the skin, whereby is formed the cutaneous depression which marks the situation of this opening. In the adult the umbilicus may be considered as a point of considerable strength; in the estimation of some it is the strongest point in the abdominal parietes: in dissecting away the skin at this point, we find subjacent to it a very condensed cellular tissue, to which and to the skin the fibrous cords into which the umbilical vessels have degenerated adhere closely; these cords, too, adhere not only to the skin, but likewise to the margin of the fibrous ring through which they pass. "The umbilical opening, therefore," says Scarpa, "in the infant two months after birth, and still more in the adult, is not only like the other natural openings of the abdomen, strengthened internally by the application of the peritoneum and of the cellular substance, and on the outside by the common integuments, but it is likewise plugged up in the centre by the three umbilical ligaments and by the urachus; these ligaments form a triangle, the apex of which is fixed in the cicatrix of the integuments of the umbilicus, the base in the liver, in the two ilio-lumbar regions, and in the fundus of the urinary bladder; by this triangle is formed a strong and elastic bridle, capable of itself alone of opposing a powerful resistance to the viscera attempting to open a passage through the aponeurotic ring of the umbilicus, which apparatus does not exist at the inguinal ring or femoral arch."*

In the fœtus the ring of the umbilicus is proportionally larger than at any period after birth when the cicatrix is fully formed: it is, however, at the full term, or even at the seventh or eighth month, and in the healthy state of the parts, equally filled up by the umbilical vessels and urachus, and we would say is equally capable of resisting intestinal protusion as at any subsequent period. Hence it may be inferred that congenital umbilical ruptures are always of very early date, being attributable to the persistence of the opening at the umbilicus, and the continuance in it of the intestinal prolongation which exists there naturally at a very early period. It may likewise be inferred that the rupture in the adult can much more easily occur in the vicinity of, than through the umbilical ring; and experience confirms this deduction from the anatomy of the parts.

* Also called enervations.—*Winslow*. They are, says Meckel, incontestably incomplete repetitions of the ribs in the walls of the abdomen.

† Hence Meckel classes it among the polygastric muscles.

* Scarpa on Hernia, p. 373.

Above the umbilicus the linea alba is from two to four lines broad in the greater part of its extent; and below the umbilicus it gradually tapers down to the pubis, at the same time increasing in thickness.*

5. *Pyramidalis (pubio-sub-umbilical).* At the inferior extremity of the recti, and separating their origin, are two small muscles of a pyramidal form; their bases are inferior, and attached to the symphysis and body of the pubis, and uniting ligaments, and their apices superior and inserted into the linea alba by small tendons, from two to three inches above the symphysis pubis. Each muscle is enveloped in a distinct sheath, and lies a little more prominently than the origin of the rectus of the same side. These muscles are not unfrequently absent. Sometimes, on the contrary, there have been two on one side and one on the other, or even two on each side.†

The muscles which enter into the composition of the posterior wall of the abdomen are chiefly those which occupy the lumbar region of the back, filling up that empty space which in the skeleton is observed on each side of the spinal column between the crista ilii and the last rib. In dissecting from behind forwards in this region, having removed the skin and lax cellular tissue already described, we come upon the strong fibrous expansion, the *fascia lumborum.* This has extensive osseous attachments, and thus firmly binds down the subjacent muscles. When it is removed, the lumbar portions of the sacrolumbalis and longissimus dorsi, and a little of the spinalis dorsi, are brought into view, the two former of which are described by some as a single muscle—the sacrospinalis. The external of these muscles is the sacrolumbalis, and its outer margin may be said to constitute the limit of the posterior wall of the abdomen in that direction. In this situation the posterior and middle layers of the tendon of the transversalis separate from each other to ensheath these muscles, the posterior layer forming the fascia lumborum. We must refer to the article Back for a particular description of these muscles.

When the lumbar mass of muscles (as the three preceding have been called) has been removed, the next part brought into view is the anterior layer of their fibrous sheath formed by the middle lamina of the transversalis tendon, which is inserted into the apices of the transverse processes. This lamina is thin and semi-transparent, so that the fibres of the muscle which lies immediately before it, are seen through it. This muscle is the

Quadratus lumborum (ilio-costal, ilio-lumbi-costal). The term quadratus is applied to this muscle, more from its quadrilateral form than from any nearer resemblance to a square, inasmuch as all its sides are unequal. The most fixed attachment of this muscle is its inferior, where it is inserted by tendinous fibres into the iliolumbar ligament and into the inner lip of the crista ilii for about an inch to the outer side of the insertion of that ligament. From these points the fibres proceed vertically upwards, the external ones going to be inserted into the inferior margin of the last rib for nearly its entire length, and the internal fibres, those in particular which are attached to the ligament, terminating by four aponeurotic tongue-like bundles, which are inserted into the anterior surface of the transverse processes of the four superior lumbar vertebræ near their bases. The several bundles which end in these tongue-like processes vary in length; those which are external being the longest, as going to higher vertebræ. This muscle is covered on its anterior or abdominal surface by the anterior lamina of the tendon of the transversalis muscle, by which it is separated from the diaphragm as well as from the psoas magnus.* The last dorsal nerve and the first two branches of the lumbar plexus, pass between the quadratus and the aponeurotic lamina which covers it.

Psoas magnus, (ψοα, *lumbus*) *(prelombo, trochanterien, lumbaris.)* The greatest portion of this muscle belongs to the abdominal region; it lies along the side of, not only the lumbar but also of a small portion of the dorsal region of the spine, lodged in the angle between the transverse processes and bodies. It passes as high up as the twelfth dorsal vertebra, to the body of which as well as to those of the four succeeding lumbar vertebræ, and to their intervening fibro-cartilages, the muscle is attached: it likewise is attached to the bases of the corresponding transverse processes, so that the intervals between the portions that are attached to the bodies, and those to the transverse processes, correspond to the intervertebral foramina or points of exit of the lumbar nerves, the anterior branches of which plunge at once into the substance of the psoas muscle to form the lumbar plexus. The several bundles which thus take their origin from the vertebræ form a thick rounded muscle, which passes nearly vertically downwards, inclining a little outwards, over the brim of the true pelvis, so as often to appear to encroach upon the circumference of the upper outlet of that cavity. A little way above Poupart's ligament the muscular fibres are inserted around a strong thick tendon. This tendon, which had commenced high up by distinct portions in the interior of the muscle, passes under Poupart's ligament over the horizontal ramus of the pubis. It descends over the capsular ligament of the hip-

* "The linea alba performs the same office in the abdomen as the sternum does in the thorax, with this only difference, that it is not formed of bone. The anterior tendons of the broad muscles are attached to it, in the same way that the cartilages of the ribs are articulated with the sternum, and the difference of tissue which exists between it and the sternum is attributable to the general difference of structure between the abdominal and pectoral cavities, the latter being formed almost entirely of osseous parts, whilst the walls of the former are fleshy and tendinous."—*Meckel.*

† Meckel says that this muscle *rarely* presents anomalies; in this he must be mistaken, as its absence is certainly not a rare occurrence.

* See *fig.* 4, *f*; see also *fig.* 5, where on one side the muscle has been removed from between the laminæ of the transversalis tendon.

joint (from which as well as from the ramus of the pubis it is separated by a bursa) over the head and along the inner side of the neck of the femur, and is inserted into the posterior part of the trochanter minor at its base, being separated by a small bursa from the surface of that process. As the tendon is passing over the ramus of the pubis, it receives by its outer margin a series of fibres from the iliacus internus muscle. At its superior portion the psoas muscle is covered by a thin fibrous expansion, which is attached on the one hand to the apices of the transverse processes, and on the other to the bodies of the upper lumbar vertebræ; this expansion, the *arcus interior* of Senac and Haller,* also called *ligamentum arcuatum*, separates the psoas from the diaphragm. Below this the psoas muscle is covered with a lax, and in some degree fatty cellular tissue, which separates the muscle from the kidney externally, and from the peritoneum and ureter within, excepting where the psoas parvus covers it, and on the right side where the vena cava lies upon it. Along its internal margin are the lumbar portion of the sympathetic, the crura of the diaphragm, more especially on the left side, and on this side too the aorta approaches a little its internal margin. The common and external iliac arteries aud veins lie along the internal margin of the pelvic portion of the muscle, which is covered by the fascia iliaca. The several branches of the lumbar plexus issue from this muscle at its external margin, and the genito-crural nerve descends in front of it inferiorly. We refer to the article on the muscles of the thigh for a further account of this muscle, its relations in the upper part of the thigh, and its actions.

Psoas parvus, (prelombo-pubien). This muscle is similar to the psoas magnus in course and position. It is very much elongated, its fleshy portion being small and tapering. Superiorly it is attached to the body of the first lumbar vertebra, and to the intervertebral substance between it and the last dorsal, and sometimes to the body of the last dorsal vertebra. The fleshy belly soon ends in a flattened tendon, which descends obliquely downwards and outwards over the anterior surface of the *psoas magnus*, and at its inferior extremity expands considerably, and is inserted along the linea ilio-pectinea near the junction of the ilium and pubis. An expansion from the margins of this tendon becomes united on the outside to the fascia iliaca, and on the inside to the internal portion of the same fascia which covers the great psoas, and passes beneath the iliac vessels to become united at the brim of the pelvis to the pelvic fascia.

We must not omit to state that the crura of the diaphragm, as they descend over the bodies of the lumbar vertebræ, (see Diaphragm,) may be regarded as entering into the formation of the posterior wall of the abdomen. The inferior wall of the abdomen is not devoid of muscle, although those muscles can exercise very little, if any influence upon the contents of the cavity. The iliac fossa affords a large surface for the attachment of one of the principal muscles connecting the thigh with the trunk. This muscle is named

Iliacus internus, (iliaco-trochantcrien.) This muscle fills up the iliac fossa, to the whole of whose concavity as well as to its margin, and the two anterior spinous processes of the ilium and the interval between them, its fibres are attached. From these several points of origin the fibres converge to form a thick and broad belly, which passes over the upper part of the acetabulum and horizontal ramus of the pubis, filling up the external portion of the space between that bone and Poupart's ligament; and it is inserted, as we have already observed, into the outer margin of the tendon of the psoas magnus, which is for that reason generally described as the common tendon of the psoas and iliacus. The anterior surface of this muscle is traversed by two of the external branches of the lumbar plexus (inguino-cutaneous), and the anterior crural nerve passes between its internal margin and the psoas magnus.

The superior wall of the abdomen is entirely formed by the muscular vault of the diaphragm, which by its contraction and relaxation exercises a considerable influence on the abdominal contents, and causes very obvious changes in the form of the cavity. The concavity of this vault is towards the abdomen, and is greater on the right side than on the left, in consequence, as it is said, of the presence of the liver on that side. It is through the several openings in this wall that a communication is established between the thorax and abdomen. The largest of these openings are, that on the right side, which is completely tendinous, for the passage of the vena cava; the opening for the œsophagus; and that for the aorta; in addition to these there is a small one behind the centre of the xiphoid appendix formed by a divarication of the anterior fibres of the diaphragm, through which the cellular tissue of the anterior mediastinum communicates with the abdominal subserous tissue. There are, moreover, openings for the transmission of the splanchnic nerves, and the continued trunks of the sympathetics, as well as of branches of the phrenic arteries and nerves, and the abdominal branches of the internal mammary. The particular description of this muscle will be given under the article Diaphragm.

4. The next element which enters into the formation of the abdominal parietes is a fibrocellular expansion, which, varying in density in different situations, lines the whole internal surface of the muscular walls. It is strongest and exhibits most of the real fibrous character in the iliac region on the anterior wall, and over the iliac fossa in the inferior. In the former situation it has received the name of *fascia transversalis,* which was applied to it by Sir A. Cooper in consequence of its close connexion with the transversalis muscle: in the latter, it is called the *fascia iliaca,* from its connexion with the iliac fossa and muscle.

* Vid. Haller Icon. Septi Transversi. Op. Minora, tom. 1.

The fascia transversalis is best seen by removing the muscles which lie anterior to it: it is then distinctly observed to extend from the outer margin of the rectus muscle internally over the posterior surface of the anterior wall of the abdomen, and gradually to assume the character of a thin but condensed cellular lamella over the abdominal surface of the lateral wall: it may, however, be traced internally as far as the linea alba behind the rectus muscle, but here it is extremely thin, and has totally lost the fibrous character. Inferiorly this fascia adheres to Gimbernat's ligament and to the reflected margin of Poupart's, from which it is said, by some French anatomists, to originate. Along the line of Poupart's ligament and external to it along the crista ilii, this fascia is united with the *fascia iliaca*, the union being indicated by a white opaque line formed by a thickening of the membrane, taking the course of Poupart's ligament and the crista ilii, except where it is interrupted for the passage of vessels or other parts. Superiorly, the fascia transversalis also degenerates into a cellular lamella, which passes on the transversalis muscle to the diaphragm. It is for a short distance above Poupart's ligament that this fascia demands most attention; here it forms the posterior wall of the inguinal canal, and at a point a little external and superior to the middle of Poupart's ligament it presents an opening or separation of its fibres, through which the spermatic vessels and vas deferens united by lax cellular tissue pass into the inguinal canal, carrying around them a funnel-shaped membrane which seems to be a prolongation from or continuation of the margins of this opening, but which is in texture merely a condensed cellular layer. This prolonged membrane is the first covering which the spermatic cord receives upon its formation, which takes place as its several constituent parts meet at the opening or slit in the *fascia transversalis*; it immediately invests the cellular tissue connecting these parts, which is the *tunica vaginalis* of the cord; as it proceeds, the cremaster muscle adheres to it from the external oblique and transversalis muscles, and this again receives at its exit through the external abdominal ring another cellular expansion, to which we have already alluded.

The opening or slit in the fascia transversalis which we have just described is denominated by anatomists the *internal abdominal ring*, although, if we speak with reference to the middle line, it is external to the opening in the tendon of the obliquus externus, which is called the external ring. It would certainly be more consistent with the ordinary use of these adjectives in anatomy to reverse their application, or if the term anterior were applied to the external ring, and posterior to the internal, every purpose would be answered.

The direction of the internal abdominal ring is vertical and inclined very slightly outwards. When the fibrous character of the *fascia transversalis* is obvious, we can generally observe two very distinct portions of it, one on each side of the ring. The fibres of the external portion pass upwards and inwards; those of the internal portion, which are generally stronger and more developed than in the external, pass upwards and outwards so as to decussate with the external fibres at the upper extremity of the ring. The outer margin of this internal portion often presents towards the ring a lunated appearance, over which the vas deferens turns at a sharp angle; it can be best seen by examining the parts from behind after the peritoneum has been removed.* The fascia transversalis is continued upwards along the posterior and lateral surface of the abdominal muscles and over the diaphragm under the form of a fine lamina of very condensed cellular membrane, which adheres pretty closely to the muscles, but especially to the diaphragm, where it seems to be incorporated with the proper cellular covering of that muscle. We refer to the article GROIN, REGION OF THE, for further particulars respecting the fascia transversalis.

In the iliac fossa we find a very distinct fibrous expansion covering the whole abdominal surface of the iliacus internus muscle. This is the *fascia iliaca*. It is seen by raising the peritoneum and the subperitoneal cellular tissue from the fossa. Inferiorly this fascia is connected with the fascia transversalis along the line of Poupart's ligament, except where that connexion is interrupted by the passage of the vessels under the ligament. That space comprises the interval between the inner margin of the tendon of the Psoas and Gimbernat's ligament; and here the fascia lies close to the horizontal ramus of the pubis, and passes behind the vessels into the upper part of the thigh, where it adheres to the linea ilio-pectinea, and seems to become continuous with the fascia lata. Externally the fascia iliaca is continuous with the fascia transversalis along the crista ilii, where an opaque line indicates the union, and just internal to which it splits to ensheath the circumflexa ilii artery. On the inner side of the iliac fossa this fascia unites with the pelvic fascia along the brim of the pelvis, this union being likewise indicated by an opaque line similar to that already noticed along the crista ilii. To arrive at this point the fascia, in proceeding from without inwards, passes over the iliacus internus, then over the psoas magnus and parvus, upon which it is thinner than elsewhere; it then passes behind the iliac artery and vein, and arrives at the pelvic margin. Posteriorly this fascia is continuous with a thin and less fibrous expansion which covers the psoas and quadratus lumborum muscles, adheres to the ligamentum arcuatum, and is identified superiorly with the cellular expansion on the diaphragm, and externally with the fascia transversalis.

It has already been stated that the iliac fascia passes behind the iliac vessels. These vessels have also anterior to them a fibrous or cellulo-fibrous expansion, which is connected on the inner and outer side to the fascia iliaca. Some

* This lunated margin is very well delineated by Cloquet in the third figure of the first plate annexed to his work on Hernia, now translated by Mr. A. M. M'Whinnie.

consider this as merely a portion of the subperitoneal cellular tissue, but I cannot help regarding it as a process from the iliac fascia itself to envelope the vessels just as that fascia envelopes the circumflexa ilii artery between two lamina at its outer margin. I have never seen an instance in which this sheath was not perfectly distinct, in some cases it is of considerable strength, but in the majority weak and transparent. It was this sheath which impeded Mr. Abernethy in one of his earliest operations for applying a ligature to the external iliac artery.*

The connexion which the iliac fascia has with the fascia transversalis at the crural arch, and the relation both bear to the iliac vessels at their exit to become femoral, suggested to Mr. Colles a comparison which is constantly referred to by anatomists. "It may he said to resemble," he says, "a funnel, the wide part or mouth of which occupies the hollow of the ilium and lower part of the abdominal muscles, and the narrow part or pipe of which passes downwards on the thigh. The mouth of this funnel may be supposed to rise as high as the upper edge of the iliac muscle, and to be turned toward the cavity of the abdomen: the pipe joins the wide part where the external iliac vessels are passing under Poupart's ligament, and it is continued down on the thigh, so low as to reach the insertion of the saphena into the femoral vein."†

From the preceding sections it appears that a fibro-cellular expansion lines the whole internal surface of the abdominal parietes. It is so likewise with the pelvis, and also with the thorax. The cavity of the cranium, too, is lined with a fibrous membrane, although of a different nature, and doubtless performing a different office.

5. Between the internal fibrous expansion of the abdomen and the peritoneum is a cellular tissue, which presents different characters in each region; it is the subperitoneal cellular tissue. Along the anterior wall it is thin and fine, except inferiorly opposite the internal abdominal ring, where it becomes more abundant, as well as in the hypogastric region, immediately above the pubis. In the iliac fossa and lumbar region it is lax and abundant, especially in the latter, where there is also a considerable quantity of fat surrounding the kidney. In the iliac fossa this cellular tissue is stretched across the crural ring, and forms what Cloquet describes under the name of *septum crurale*. On the superior wall it is extremely fine, and in very small quantity. Immediately behind the sternum, and in the middle line, this cellular tissue communicates with that of the mediastinum through a separation of the anterior fibres of the diaphragm.

This subserous cellular tissue forms the primary covering of all herniæ, which push a peritoneal sac before them, and as being the fascia constituting the nearest investment of the sac, it is generally called the *fascia propria*.

* Abernethy's Surgical Works, vol. i. p. 225.

† Colles' Surgical Anatomy, pp. 68, 69.

Opposite the crural canal this cellular tissue is often so abundant, as, when condensed by the pressure of the hernial tumour, to form an expansion over the sac of considerable thickness. Sometimes it contains fat, and not unfrequently we find a large lymphatic ganglion in it, filling up the crural ring.

6. *Peritoneum.*—A considerable part of the abdominal surface of the walls of the abdomen is lined by a very fine transparent serous membrane—the peritoneum, which is likewise connected, to a greater or less extent, with every viscus within the cavity. In consequence of this double connexion, it happens that in various situations the peritoneum is reflected from the wall of the abdomen upon an adjacent viscus, and thus are produced various folds of this membrane, which demand the attention of the anatomist. These folds are rendered distinct when such a section of the anterior abdominal wall is made as without dividing them to allow of it being held apart from the viscera. I shall enumerate these folds in describing the relation of the peritoneum to the several walls. The anterior wall of the abdomen is entirely lined by peritoneum, and has in connexion with it four folds, all of which, as it were, radiate from the umbilicus. In the adult these folds are reflected round four ligamentous cords (three of which are the remains of bloodvessels in the fœtus), which meet at the umbilicus and diverge, one upwards, backwards, and to the right side *(the obliterated umbilical vein)*, two downwards and outwards towards Poupart's ligament on each side, so as to pass behind the inguinal canal, nearly midway between the two rings *(the obliterated umbilical arteries)*, and the fourth nearly vertically downwards along the middle line to be inserted into the apex of the bladder *(the urachus)*. The four folds are similar in direction to that of the fibrous cords contained within them: the fold which passes upwards towards the liver is falciform, the concavity being directed downwards and backwards. From its connexion with the convex surface of the liver it is also called the falciform ligament of the liver, and the fibrous cord contained in its inferior margiu, the ligamentum teres. The inferior and external folds pass each from the umbilicus, downwards and outwards to the iliac fossa, to a point a little on the inner side of the internal abdominal ring, where it disappears, being continued externally over the iliac fossa, and internally behind the rectus muscle. This fold, when stretched towards the umbilicus, evidently forms the partition between two pouches, *the external and internal inguinal pouches*, which correspond respectively to the internal and external abdominal rings, and indicate the situations at which make their escape those two forms of inguinal hernia, which, from their connexion with these pouches, are called by Hesselbach external and internal inguinal herniæ; the former being that by oblique descent, the latter that by direct descent.

The fourth or vertical fold indicates the reflection of the peritoneum from the anterior abdominal wall upon the superior fundus and posterior surface of the bladder: when that viscus is empty and contracted, this fold disappears totally; it is more apparent when the bladder is partially filled, and is still more distinct in the fœtus in consequence of the greater size of the urachus at that period. Just above the pubis the peritoneum is connected to the abdominal wall by a very lax cellular tissue; and accordingly when the bladder is much distended, the peritoneum is pushed upwards, and stripped off the abdominal wall to an extent proportioned to the degree of distension of the bladder, so that its anterior surface is then in immediate contact with the abdominal wall, and may be opened with impunity so far as the peritoneum is concerned.

The lateral walls of the abdomen are likewise completely lined by peritoneum, which extends backwards as far as the junction of these walls with the posterior, where it is reflected from them so as to involve the ascending colon on the right side and the descending on the left, and here it forms on each side the folds respectively termed right and left *mesocolon.* From the right lateral wall the peritoneum is continued upwards upon the diaphragm, and contributes to form the right lateral ligament of the liver; on the left side it is continued in a similar manner on the diaphragm, and in passing from the spleen to that muscle forms the fold called *splenico-phrenic.*

The concave surface of the diaphragm is in greatest part lined by peritoneum: the anterior half of the muscle is uninterruptedly covered by peritoneum, which adheres very closely to the central tendon, but is much more easily separated from the muscular portion. On the right side and in the middle, in front of the œsophageal opening, the peritoneum is reflected from the diaphragm to the liver, forming the right lateral, coronary, and left lateral ligaments of that organ. The posterior half of this surface is likewise covered by peritoneum, that membrane being deficient for a little way behind the opening for the vena cava and behind and on each side of the œsophageal and aortic openings: the crura of the diaphragm are covered chiefly on the outer side.

The peritoneum comes into immediate contact with the posterior abdominal wall only in a very small portion of its extent: in tracing it on the right side we find it covering the right colon, then passing inwards over the kidney and suprarenal capsule, the duodenum and vena cava, to the crus of the diaphragm above, and in the middle and below, where it also covers the vena cava, and the renal vessels, to form the right or superior lamina of the mesentery. On the left side it covers in a similar manner the left colon, the left kidney and capsule, and that portion of small intestine which projects just to the left of the superior mesenteric artery, which may be regarded as the commencement of the jejunum; below this it manifests its continuity with the layer of the opposite side by forming the left or inferior lamina of the mesentery. This lamina commences at the left side of the body of the second lumbar vertebra; as it descends, it gradually crosses more in front of the aorta, so as to terminate at the right sacro-iliac symphysis; the right lamina is situated quite on the right side of the spine.

In the iliac fossæ the peritoneum is in connexion with the *fascia iliaca,* except where it is separated by the cœcum on the right side (on which side it sometimes forms a fold termed *mesocæcum,*) and by the sigmoid flexure on the left. Internal to these portions of intestine on each side, the peritoneum covers the external iliac artery and vein, from which it is separated by a very loose and sometimes adipose cellular tissue, and by a process of the iliac fascia, to which allusion has already been made.

From the preceding description of the connection of the peritoneum with the parietes of the abdomen, it will appear how few are the situations at which the surgeon could cut through any portion of these walls without risk of wounding the serous membrane. Immediately above the pubis this may be done in consequence of the abundance of cellular membrane there which separates the serous membrane from the wall; but in the contracted state of the bladder the operator must proceed with the greatest caution: in the distended state of that viscus, however, the wall of the abdomen is deprived of its lining to an extent proportionate to the height to which the bladder ascends behind the recti muscles; and accordingly it is under such circumstances that the paracentesis vesicæ supra pubem, and the high operation for the stone may be performed with impunity to the serous membrane. At the posterior wall an instrument may be passed into any part of the posterior surface of the kidney without injury to the peritoneum; the pelvis of the kidney, or any part of the abdominal course of the ureter, may be opened too, or the vena cava; and by cutting into the bodies of the vertebræ, and the muscular portion of the posterior wall in the dead body, a view of all the parts which lie upon that wall may be obtained without at all injuring the peritoneum.*

Further details respecting the anatomy of the peritoneum will be found in the article under that head.

Vessels and nerves of the abdominal walls.— *a. The arteries.*—The most important arterial ramifications are found in the anterior wall. In the superficial fascia we find the *superficial epigastric* artery or tegumentary artery, which exists as a trunk in the iliac regions. This artery, arising from the femoral, pierces the fascia lata, and passes over Poupart's ligament upwards and inwards, crossing the anterior

* The reader may examine with advantage, Ludwig, Icones cavitatum thoracis et abdominis a tergo apertarum. Leipzig, 1789.

wall of the inguinal canal between the two rings; it is distributed in the integuments and fascia of the iliac and umbilical regions, and anastomoses with its fellow of the opposite side, and by deep branches which pierce the aponeuroses, with the deep epigastric artery. In the epigastrium and hypochondria the superficial fascia and integument are supplied by cutaneous branches from the internal mammary and the inferior intercostals. The deep-seated parts of this region are likewise supplied from the last-named arteries; the largest and most constant of which is the abdominal branch of the internal mammary, which in the sheath of the rectus supplies that muscle, and establishes an important communication with the epigastric: this anastomosis is said to have been known to Galen, who by it proposed to account for the sympathy which exists between the uterus and the breasts.* Another branch of the mammary supplies the muscles external to the rectus; it runs between the obliquus internus and transversalis, and is lost in anastomosing with the inferior intercostal, the lumbar, and the circumflexa ilii arteries.

Inferiorly, the abdominal wall is supplied by two considerable and very constant arteries, viz. the *epigastric*, which may be distinguished from the artery that supplies the integuments by the appellation *deep*, and the *circumflexa ilii*. The *epigastric artery* arises in general from the external iliac a little way above Poupart's ligament; it at first inclines downwards to that ligament, and then turns upwards, and directs itself forwards and inwards, crossing the iliac vein; it then runs along the posterior surface of the anterior wall of the abdomen, inclosed between the peritoneum and fascia transversalis, at first situated between the external and internal abdominal rings, and on arriving at the rectus muscle, the sheath of which it enters about two inches above the pubis, it gives off branches from either side to the abdominal muscles and peritoneum, and behind the linea alba, establishes a very free inosculation with its fellow of the opposite side. As it lies behind the inguinal canal, the epigastric artery is much nearer to the internal than to the external abdominal ring, being to the pubic side of the former; here the vas deferens, as it passes up from the pelvis to the inguinal canal, hooks over it, and receives one or two small branches from it. In passing to the rectus muscle, this artery lies internal to the linea semilunaris. It enters the sheath of the rectus, and then terminates by anastomosing with the internal mammary. The course of this artery demands particular attention from the surgical anatomist in reference to the operations for inguinal herniæ, and to that for paracentesis abdominis, when the abdomen is perforated in the linea semilunaris. The trunk of the artery is so distant from the linea alba in its whole course, that it is free from danger in any operation performed in that line, or in the internal half of the rectus muscle, and its security in such operations is increased under the altered state of parts consequent on pregnancy, ascites, or any abdominal tumour pressing similarly on the abdominal wall. In these cases the distance of the artery from the linea alba is increased by the flattening of the rectus muscle, which results from its compression. — (See Groin, Region of; Hernia; Iliac Artery.)

The *circumflexa ilii* artery comes likewise from the external iliac, near to the origin of the epigastric; it passes upwards and outwards towards the spine of the ilium, runs along the line of junction of the fascia iliaca with the fascia transversalis, covered by the fascia, and follows the circumference of the iliacus internus muscle to end in anastomosing with the iliolumbar artery. From that part of the artery which intervenes between its origin and the spine of the ilium, come the principal branches which it supplies to the abdominal muscles.

The lateral and posterior walls of the abdomen are supplied by the inferior intercostals, the lumbar, the iliolumbar, the circumflexa ilii arteries; the superior walls by the phrenic branches of the internal mammary and by those of the aorta. It is in cases where the aorta has been obliterated that we can see best the extent of arterial ramification on the abdomen, and can appreciate the benefit of these numerous anastomoses, and the connexion which they establish between the upper and lower portions of the aorta.*

b. The veins.—The veins of the abdominal parietes are much more numerous than the arteries; each artery has its accompanying vein or veins, but those which are especially deserving of attention are the tegumentary veins which accompany the superficial epigastric artery, and those which ramify along with the deep epigastric and mammary. The subcutaneous veins demand attention in consequence of the considerable size which they sometimes attain; this enlargement is commonly attendant on ascites and on pregnancy, and is occasionally, to a remarkable extent, a consequence of some irregularity, obstruction† or retardation of the circulation, in the deep-seated veins of the abdomen, more especially the inferior vena cava. The veins which accompany the superficial epigastric artery empty themselves by one or more trunks into the *vena saphena* at the upper part of the thigh.

Two veins generally accompany the deep epigastric artery, which empty themselves into the external iliac vein. These veins are equally subject to enlargement with the preceding, and from similar causes, and they are often found in a varicose condition in women who have borne many children.

Some curious anomalies have been observed in the venous circulation of the anterior abdominal wall, which, as being calculated to interfere with the operator, the practitioner would

* Dict. de Médecine, art. *Abdomen*.

* See the interesting case of obliterated aorta recorded by Messrs. Crampton and Goodissen. Dub. Hosp. Reports, vol. ii.

† As in the case of obliteration of the inferior vena cava from the pressure of an aneurismal tumour observed by Reynaud. Journal Hebdom. de Méd. vol. ii. p. 110.

do well to note. M. Meniere* has described a case in which a very large vein, arising from the external iliac, passed up along the linea alba to the umbilicus, was continued along the obliterated umbilical vein, and opened into the vena portæ. In another case, recorded by Manec, the vein originated in the same manner by two roots, reached the umbilicus, taking a course parallel to the umbilical artery, formed an arch outside the navel, and having re-entered the abdomen, opened into the vena portæ. In another instance which occurred to Cruveilhier the superficial veins in the hypogastric region were enormously enlarged, at the umbilicus they ended in a trunk as large as a finger, which communicated with the vena cava as it passed under the liver.† Berard proposes to explain, by the supposition of the existence of such anomalies as those above described, the occurrence of fatal hemorrhages from wounds inflicted at the umbilicus, which have been attributed to the persistence of the umbilical vein.‡

c. The lymphatics.—Those on the anterior wall communicate above with the axillary glands, and below with those of the groin: the deep-seated lymphatics of the posterior wall communicate with the glands which lie along the lateral and anterior surfaces of the lumbar spine.

d. The nerves.—The nerves of the abdominal parietes are derived from the inferior intercostals and from branches of the lumbar plexus. The seventh, eighth, ninth, tenth, eleventh, and twelfth intercostal nerves terminate in supplying the transverse and oblique muscles and the recti; the twelfth lies in front of the quadratus lumborum muscle, and gives several filaments to that muscle. The ilio-scrotal and inguino-cutaneous nerves are the branches of the lumbar plexus which mainly supply the inferior part of the oblique and transverse muscles. One branch of the genito-crural, which is found in the inguinal canal, also sends some twigs to these muscles.

The posterior wall is supplied by the subdivisions of the posterior branches of the lumbar nerves.

Physiological action of the abdominal parietes and muscles.—We have already alluded to the peculiarity which distinguishes the abdominal cavity when compared with the other great cavities, namely, that its walls are in greatest part composed of contractile tissue. At first view the muscular apparatus of the abdomen would appear to be a great constrictor muscle destined principally to exert its influence on the cavity and its contents; but when we take into account the attachments of those muscles to the ribs, the vertebræ, and the pelvis, it becomes evident that they must likewise be destined to act upon the thoracic and pelvic cavities, as well as upon the vertebral column. In the constitution of the abdominal parietes we observe, as Berard* remarks, the most happy adaptation of structure to uses. A completely osseous covering would have greatly interfered with the functions of the abdominal organs, which are liable to experience changes both extensive and often very rapid, either by reason of the introduction of alimentary matter, whether solids or fluids, or by the disengagement of gases within the digestive tube, or by the progressive development of the impregnated uterus. We may moreover add that an exact repetition of the structure of the walls of the thorax would not have been well adapted to the abdomen for the same reason, namely, the too great resistance which it would afford to compression from within, thereby interfering with the distensibility of the enclosed viscera. The resistance, too, which a wall so constituted would afford to impulses from *without* could not have been so easily adapted to the impetus of the forces likely to act upon them as a purely muscular wall whose contractions and the intensity of them are obedient to the will.

The consideration of the action and uses of the abdominal muscles naturally comes under two heads:—1. their action upon the abdominal cavity and its contents; 2. their influence on the trunk generally, or parts of it.

It is the muscles that enter into the composition of the anterior and lateral walls of the abdomen which act chiefly on the cavity and its contained viscera. The solidity of a considerable portion of the posterior wall, and the great strength of the lumbar muscles, give to that wall such a power of resistance as enables it to receive the compressed viscera without at all yielding. A reference simply to the attachments of the muscles of the anterior and lateral walls is sufficient to shew that these muscles when contracted must diminish the capacity of the abdomen, both in the lateral and antero-posterior directions; and as the posterior wall is but little influenced, the viscera will be pushed partly upwards against the diaphragm, and partly downwards into the cavity of the pelvis, where their further descent is opposed by the levator ani. Hence it appears that a degree of antagonism exists between the diaphragm and the abdominal muscles, as well as also between those muscles and the levator ani. It is extremely difficult to maintain the abdominal muscles and the diaphragm at the same moment in a state of contraction; in general they alternately yield the one to the other: and when it does happen that they are simultaneously contracted, the abdominal viscera must suffer an unusual degree of compression; and it is not improbable that vomiting is sometimes produced by such a cause, and defecation, no doubt, is likewise aided by it. The danger of the protrusion of some of the hollow viscera between the fibres

* Archives Gén. de Méd. t. x. p. 381. The vascular distribution which existed in this subject presents, as Meniere has remarked, a striking similarity to that which is naturally found in the Saurian, Ophidian, and Batrachian reptiles, viz. a division of the general venous system which communicates with the hepatic vena portæ.

† Velpeau, Anat. Chir. ed. 2. vol. ii. p. 32, and Manec, Dissertation inaugurale. Paris, 1826.

‡ Dict. de Méd. art. *Abdomen*.

* Loc. cit.

of the muscles is provided against by the variation of direction in the fibres of the several layers; thus the fibres of the obliqui are in the directions of two intersecting diagonals, and those of the transversalis are different from both. By this arrangement a sort of network is formed, with meshes so small as to render a protrusion perfectly impossible in the healthy condition of the muscle. In the compression of the viscera the abdominal muscles are most completely congeneres, although the transversalis seems to be the best adapted to this action, and probably, for that reason, forms the layer which is placed nearest the peritoneum. The recti muscles are powerful auxiliaries in affording a fixed point of attachment in front for the aponeuroses of the broad muscles, and the pyramidales assist in a similar manner by rendering tense the linea alba. Is this constant action of the abdominal parietes on the viscera necessary or favourable to the due performance of the functions of those organs, or to the continuance of the abdominal circulation? There certainly does not appear to be any evidence for the *necessity* of them for this purpose: that they are favourable to it may be inferred from the fact that they do bear their present relation to them. We know from numerous experiments on animals, that both the transmission of the intestinal contents, and the abdominal circulation may go on when the abdominal muscles have been freely opened or removed. Hence we may answer this question with perfect justice in the words of Bichat: "The walls of the abdomen favour these functions by their motions; but these motions are by no means essential to them."

It is in consequence of the power which the abdominal muscles thus appear to exert in compressing the viscera, that some physiologists have attributed the act of vomiting to their action united with that of the diaphragm; and Magendie, reviving the opinions of Bayle, Chirac, and Shwartz,* went so far as to deny to the muscular coat of the stomach any participation in this act, and to ascribe it wholly to the influence of the abdominal muscles. But Beclard, to whom the question was referred by the Academy of Medicine of Paris, proved satisfactorily that the abdominal muscles are active in producing vomiting when the stomach is distended in a certain degree, and that the muscular coat of the stomach is also active in emptying the contents of that viscus. This conclusion Haller had arrived at long ago, and clearly expresses it in the following passage: "Evidentissimum ergo videtur, vomitus quidem causam esse in ventriculo eumque in contractionem niti propriis viribus atque aliquando vomitum perficere. Plerumque tamen irritationem in ventriculo natam et sensum summæ anxietatis, quæ vomitum præcedunt, facere ut ad levandam ægrimoniam vires diaphragmatis et musculorum abdominis excitatæ atque molestiam de homine amolituræ, vomitum perficiant. Unde neque a solâ voluntate in plerisque certe mortalibus vomitus cieri potest neque a solâ absque voluntate natura—Quare recte conjunctas vires ventriculi et organorum respirationis Cl. Viri fecerunt. Et videtur diaphragma et abdomen plus virium habere, quando ventriculus aut cibis repletus est, aut clausis ostiis distentus: tunc enim magis ad perpendiculum proximum ventriculum comprimunt et tota contingunt."*

If it be admitted that the abdominal muscles are active in producing vomiting, and in defecation and micturition, it will follow likewise that they must assist in parturition. While these pages were preparing for press, the following passage presented itself to me, in an able and interesting review of M. Velpeau's Treatise on Midwifery. It so fully illustrates the part which the abdominal muscles take in promoting parturition, that I venture to transcribe it, "It is certain," says the reviewer, "that a woman who 'bears down' as it is termed, with all her force, who makes the most of her pains, however feeble they may be, will thus accelerate her delivery; and that another may more or less delay delivery by voluntarily opposing muscular action as much as she can. For example;—a woman was admitted for delivery at M. Baudelocque's theatre; labour went on regularly, and the pupils assembled. The dilatation of the cervix now slackened, and no progress was made during the whole night. The *élèves* were fatigued and retired; the pains immediately returned, and dilatation again went on. The young men again entered; the phenomena of labour again ceased. Baudelocque, suspecting the cause, gave a hint to the students to retire, but to be at hand and enter upon a given signal. The patient now began to 'bear down,' and the head of the child was quickly at the vulva. The spectators were once more brought to the scene of action, and the labour was speedily terminated; for it had now advanced too far to be suspended by any voluntary effort or moral alarm of the woman."†

The fixedness of the inferior attachment of the abdominal muscles to the pelvis, and the mobility of the ribs, to which they are attached superiorly, evidently indicate that these muscles are destined to act upon the thoracic cavity. The transversalis does not, from the direction of its fibres, admit of this action to any extent; that office, therefore, devolves chiefly on the obliqui and recti. When these last-named muscles act together, they must compress the inferior opening of the thorax, draw its inferior margin downwards and backwards, and, by the compression thus exerted on the abdominal viscera, push them upwards against the diaphragm, which muscle is thus made to ascend into the thorax, and that cavity is thereby diminished in its vertical and antero-posterior diameters, and also, though not so obviously, in its transverse. Hence the lungs become so compressed as to be adapted to the altered capacity of the

* Vide Haller, Elementa Physiologiæ, t. vi. sect. iv. § xiv.

* Haller, ubi supra. See, also, Richerand, Physiologie par Berard, art. Digestion, § xxiv.

† Medical Quarterly Review for April, 1835. p.100.

thorax, and thus these muscles must be considered as very important agents in the act of expiration. It must be observed, however, that in order that they may act on the chest with their full force, it is necessary that that cavity should have been previously in a state of full dilatation, for under such circumstances the fibres of the obliqui and recti are considerably stretched and their levers elongated.* It is in the excited states of expiration, coughing, sneezing, &c., that this action of these muscles is most obvious.

But it is in the motions of the trunk that the abdominal muscles are called most into play. In all the inflexions of the trunk, whether the body be horizontal or erect, these muscles are main agents. When the body is recumbent on a horizontal plane, the recti are thrown into action when the individual attempts to raise up the thorax, the spine being thereby brought into the state of flexion. If the thorax be fixed, while the body is still supine, the action of the recti will draw the pelvis upwards and forwards, causing slight flexion of the spine, and slightly approximating the upper margin of the pelvis to the lower margin of the thorax. Although the recti muscles are the principal agents in thus flexing the spine, the *obliqui* co-operate with them very powerfully, and are especially useful in maintaining the due proportion between the middle and lateral regions of the abdomen. When the two obliqui of the same side act together, the direction of their force is, as with all oblique muscles whose fibres decussate, in the diagonal between their fibres; and, therefore, when the obliqui of opposite sides act in unison, they very powerfully aid the recti in flexion of the spine, approximating the thorax and pelvis anteriorly. When the obliqui of one side act, they produce a lateral inflexion of the trunk to that side,—the middle and opposite region of the abdomen being in this position rendered prominent by the viscera pushed over from the side of the contracted muscles. In what have been called the rotatory motions of the trunk, the obliqui muscles of the same side antagonize each other; thus in that movement by which the anterior surface of the trunk is made to look to the left side, the obliquus externus of the right side will co-operate with the obliquus internus of the left, but the obliquus internus of the right will antagonize the external muscle of the same side. "These muscles," *(obliqui externi et interni,)* says Dr. Barclay, "from occupying the whole of the lateral aspects extending between the ilia and ribs, and from acting at the greatest lateral distance from the centre of motion, must always be muscles principally concerned in producing inflexions dextrad and sinistrad on the lumbar vertebræ, principal directors in all the inflexions sternad and dorsad; and, from the assistance which they give to the recti, principal librators also of the trunk, whether we be sitting, standing, or walking."

The reciprocal action of the recti and obliqui on each other is one of the most beautiful parts of the mechanism of the abdominal muscles. This is mainly to be attributed to the close connection which subsists between these muscles in consequence of the formation of the sheaths of the recti by their aponeuroses, and the adhesion of the anterior wall of those sheaths to the tendinous intersections of the recti. When the recti contract, the antero-posterior diameter of the abdomen is diminished, and consequently the viscera are pushed towards the sides; when, on the other hand, the obliqui contract, they diminish the transverse diameter of the abdomen, and push the viscera forward in the middle line. In the one case, then, it will be evident that the obliqui act as moderators to the recti, and in the other the resistance of the recti moderates the action of obliqui,—the former muscles being, as Cruveilhier remarks, as it were, two active pillars compressing forcibly the viscera against the anterior surface of the spine. It is probably to enable the recti to act more completely as moderators upon the several segments of the obliqui that they are intersected by tendinous lines, with which the aponeuroses of those muscles are connected. Another use has been assigned to these intersections by Bertin, viz.,—to multiply the points of attachment of the obliqui muscles, and to associate them, in many actions, with the recti muscles. This is explained by a reference to the action of the recti in flexing the pelvis: were these muscles unconnected with the obliqui, they would act only on the pelvis, into which they are inserted; but in consequence of the insertion of the internal oblique into the intersections of the recti, and the attachment of that muscle also to the crista ilii, the force of contraction of the recti is communicated not only to the pubis, but also through the fibres of the obliquus internus to the rest of the pelvic margin.*

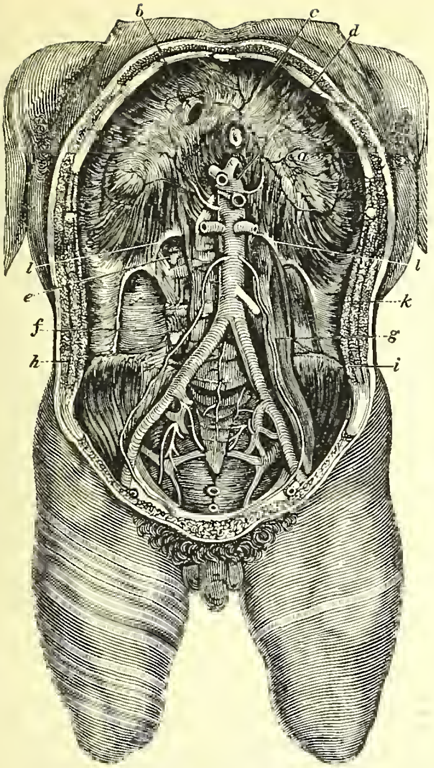
The action of the pyramidales seems to be chiefly on the linea alba, which they render tense; thus limiting the separation of the recti, and opposing the tendency to visceral protrusion. Fallopius supposed that they acted on the bladder, especially when it was in a distended state; and Parsons conjectured that they might depress the suspensory ligament of the bladder (the urachus), and thus facilitate the contraction of that organ.

The other muscles which are from situation abdominal muscles in consequence of their connexion with the posterior wall of the abdomen, are chiefly agents in the extension of the vertebral column: in their contracted state, however, they form a tense and resisting surface, against which the viscera are compressed by the contraction of the anterior muscles.

II. *Of the Abdominal Cavity.*—The annexed engraving (*fig.* 5.) exhibits a view of the abdominal cavity, the anterior and part of the lateral walls having been cut away and the viscera removed. The subject is so bent backwards as to render the bodies of the vertebræ very

* Barclay on Muscular Motion, p. 522.

* Berard, loc. cit., et Bertin, sur l'usage des enervations des muscles droits du bas-ventre, in Mém. de l'Acad. des Sciences de Paris.



(*Fig. 5.*)

prominent anteriorly, and the continuity of the abdominal and pelvic cavities is thus clearly shewn. It is useful to examine the relations of the axes of these two cavities; that of the pelvis passes forwards and upwards towards the umbilicus, while the axis of the abdomen passes from above downwards and forwards so as to terminate a little above the pubis, the two axes accordingly would intersect each other a little below the umbilicus at an obtuse angle. This angle may be obliterated by bringing the pelvis very much forward and producing a full flexion of the spine, and hence in all efforts for expulsion that attitude is almost instinctively assumed which shall identify the axes of the two cavities, and thus direct the efforts in the most favourable manner. The ordinary form of the cavity in the adult male is oval, but it presents some slight differences in the female and in the fœtus; and these differences are dependent on the great or incomplete development of the pelvis. In the female the abdomen is generally more capacious than in the male; and this greater size is more remarkable at the inferior part of it in the hypogastric region. In fact in the male it would seem that the great extremity of the oval is toward the thorax, and its smaller one towards the pelvis; but in the female it is just the reverse, the larger extremity being toward the pelvis. It should be observed, however, that the modern fashion of tightly compressing the lower part of the thorax has a material effect on the external characters of the female abdomeu, otherwise there is no reason that the superior part of it should be proportionally less than in the male. In the fœtus the abdomen is proportionally larger than at any other period of life: this is to be attributed to the imperfect development of the pelvis, and likewise to the great size which some of the abdominal viscera possess; and as some time must elapse before the pelvis reaches its full dimensions, or the viscera lose their superfluous parts, the abdomen continues of this large size for a long period after birth.

The subdivision of the abdomen into regions is especially useful in reference to the contents of the abdominal cavity, which it is highly desirable the student should examine, so as to be able to assign to each compartment its appropriate contents. The abdominal viscera may be subdivided into the membranous and the parenchymatous; the former being such as the stomach and intestinal canal, the latter, such as the liver, spleen, pancreas, &c. The viscera have likewise been distinguished in reference to their position with respect to the peritoneum, by the names *intra-peritoneal* and *extra-peritoneal;* but it is sufficient to know that no serous membrane contains any organ within it (*i. e.* within its sac) to see the error of such a distinction. But we cannot adopt a better division of the abdominal viscera than that which has reference to the functions of those organs, and which Beclard has adopted: viz. 1. the organs of digestion—the stomach, the intestinal canal, the liver and its appendages, the spleen, and the pancreas: 2. the urinary organs—the kidneys and the ureters, to which may be added from their close relation to the kidneys, the suprarenal capsules: 3. the organs of generation in the male—the vasa deferentia, and in the male fœtus at the sixth or seventh month of intra-uterine life, the testicles: none of the organs of generation can strictly be said to be abdominal organs in the female. In both male and female the other internal generative organs are *pelvic* viscera. If we add to the above enumeration of parts the abdominal portion of the aorta, its primary subdivision into the common iliacs; the anterior subdivision of these arteries under the name of external iliacs; the branches of the aorta which are distributed to the viscera as well as to the walls of the abdomen; the common and external iliac veins; the vena cava ascendens; the system of the vena portæ; the abdominal portion of the sympathetic system of nerves, both that which follows the arterial ramifications, and that which is the continuation of the chain of ganglia that lies along the spine, the termination of the par vagum; the mesenteric glands, and the lacteals; the lymphatics and their ganglia which lie along the spine; the origin of the thoracic duct, a portion of the course of that duct;—these will complete the list of parts contained in the abdominal cavity.

The full particulars of the relative positions of the contents of the abdomen, and the abnormal states of that cavity, both congenital and morbid, including also the abnormal states of its parietes, we prefer to bring together in a separate article under the head Cavity abdominal, to which we beg to refer the reader. The special anatomy, both natural and abnormal, of the several abdominal viscera is distributed among the articles Intestinal Canal, Kidney, Liver, Pancreas, Spleen, Suprarenal Capsule.

Bibliography.—The several systematic writers, as *Winslow, Boyer, Portal, Bichat, Meckel, Cloquet, Marjolin, Hildebrandt*, &c. for the titles of whose respective works see the Bibliography of Anatomy, (*Introduction.*)—*Velpeau*, Anat. Chirurgicale. Paris, 1833. t. ii. *Blandin*, Anat. Topographique. *Cruveilhier*, Dictionnaire de Méd. et Chirurg. art. *Abdomen*. *Beclard* et *Berard*, Dict. de Médecine. Ed. 2d. art. *Abdomen*. *Pierer* Anatomisch-Physiologisches Realworterbuch. herausgegeben von J. F. Pierer. Leipzig, 1816. art. *Abdominalmuskeln*. *Gerdy*, Anat. des formes extérieures. Paris, 1829. p. 122 and 199. *Cloquet*, Recherches Anat. sur les Hernies de l'Abdomen, or the translation by McWhinnie. Lond. 1835. *Scarpa*, on Hernia, by Wishart. *Lawrence* on ditto. *Todd*, on ditto. Dub. Hosp. Reports, vol. i. *Flood's* plates of Inguinal and Femoral Hernia. Lond. 1834. *Camper*, Icones Herniarum. *Guthrie*, on Inguinal and Femoral Hernia. *A. Cooper*, on ditto, and on the Testicle. *Manec*, Dissertation Inaugurale sur l'Hernie. 1826. *Colles's* Surgical Anatomy. Dublin, 1811. *Barclay* on Muscular Motion, p. 337 et sqq.

(*R. B. Todd.*)

ABSORPTION in physiology (from *absorbeo*: Lat. *absorptio*, Fr. *absorption*, Ger. *die einsaugung*, Ital. *assorbimento*.) The term absorption is employed in physiology to designate a vital organic function, the primary or immediate object of which is to furnish the system with a due supply of matter for its growth and subsistence. It is proposed, in the following article, first, to give an account of the organs by which the function is performed; this will lead us, 2dly, to consider the question of venous absorption; in the third place, we shall inquire into the mode in which the absorbents act; and, lastly, we shall offer some remarks upon the specific uses of the different parts of the absorbent system, and upon the relation which it bears to the other vital functions.

§. 1. *Description of the Absorbent System.*—We propose, in the first instance, to restrict the term *absorbent system* to those organs, which are supposed to be exclusively appropriated to the function of absorption; these may be included under the two heads of vessels and glands, the vessels being again subdivided into the lacteals and the lymphatics.

Although the absorbents are distributed to almost every part of the body, and perform so important an office in the animal economy, they were among the organs which were the latest in being discovered by anatomists. There are, indeed, some passages in the writings of Galen,* which would lead us to suppose that certain parts of the absorbents had been seen by Erasistratus and Herophilus, as well as by himself; but it appears that they were, all of them, unacquainted with the relation which these vessels bore to the other organs, and were entirely ignorant of their office and destination. These scanty observations of the ancients seem to have been entirely neglected, or even forgotten, until the study of anatomy was revived, together with that of the other medical sciences, in the sixteenth century. In the course of the researches which were then made into the structure of the animal body, various parts of the absorbent system appear to have been brought into view, and are noticed, among other writers, by Fallopio,* who discovered the lymphatics, connected with some of the abdominal viscera, and by Eustachio,† who detected the thoracic duct. But although their descriptions, especially that of Eustachio, are sufficiently correct to enable us to identify them, as forming a part of the absorbent vessels, yet they were unacquainted with their specific nature and office, and with their relation to the sanguiferous system.

It is generally admitted that the merit of the discovery of the lacteals is due to Aselli; this discovery he made in the year 1622. While he was examining the abdominal viscera of a dog, he observed a series of vessels attached to the mesentery, which appeared to have no direct connexion with the arteries or veins, and which, from the circumstance of their containing a white opake fluid, he denominated Lacteals.‡

He regarded them as a distinct set of vessels, exercising a specific function, distinct from that of the sanguiferous system, and he ascertained that they took their origin from the surface of the intestines, and proceeded towards the more central parts of the body, but it was not until the year 1651, that their termination in the thoracic duct was discovered by Pecquet.§

The discovery of the other species of absorbent vessels, styled, from the appearance

* De Anat. Admin. lib. 7, sub finem; De usu partium, lib. 4. cap. 19; An sanguis in arteriis &c. cap. 5.

* "Observ. de Venis," lib. 3., in Op. p. 532; first published in 1561. We may add the names of Fabricio, Piso, and Gassendi, who appear to have seen certain parts of the lymphatics, although they were not aware of their specific nature. See Bartholin, de Lact. Thor. c. 2; and Mascagni, Vas. Lymph. Hist. Proleg. sub init.

† De Vena sine pari, Antig. 13, sub finem, in Opusc. Anat.; first published in 1564. See Haller, Bibl. Anat., p. 224; also Douglas, Bibliog. Anat., p. 99.

‡ Dissertatio de Lactibus; first published in 1627. See Bartholin, de Lact. Thor., c. 4; Sheldon on the Absorbent Syst., p. 20, 1. Aselli's work is accompanied by plates of very rude execution, but sufficiently expressive of the object.

§ Exper. nova anat.; first published in 1651; Bartholin, c. 5. In 1652, Van Horne published the first plate of the thoracic duct. There is some reason to suppose that Vesling had an imperfect view of it previous to Pecquet; he published his Syntagma Anat. in 1647. In describing the pancreas he speaks of the venæ lacteæ, lately discovered by Aselli, which convey the chyle to the liver, and figures them in tab. 4. fig. 3.

of the fluid which they contain, the lymphatics, was posterior to that of the lacteals. The transparency of their contents rendered them less conspicuous and less easy of detection, so that, although certain parts of them appear to have been seen by Fallopio, and afterwards by Aselli and others, yet it was not until the year 1650, that they were distinctly recognized, and their connexions ascertained. The discovery of the lymphatic system was the subject of a warm controversy between Bartholin and Rudbek, on the merits of which we are, after so long an interval, scarcely able to decide. It appears, however, to have been the opinion of Haller, and the most distinguished anatomists of the last century, that the lymphatics were detected, in the first instance, by Rudbek; that Bartholin had some intimation of the discovery, that he then took up the subject, and pursued it much farther than it had been done by Rudbek.*

There is a third individual, on whose behalf a claim of priority has been made, which possesses at least considerable plausibility. We are informed by Glisson, that an English anatomist of the name of Joliffe distinctly recognized and exhibited the lymphatics of many of the abdominal viscera, previously to the alledged discovery of either Rudbek or Bartholin.† But even if we allow Joliffe the full merit both of discovering these vessels, and being aware of their specific nature, it does not appear that he published his discovery, so that it will scarcely affect the rival claims of the former anatomists. The discovery of the absorbent or conglobate glands, as they have been termed, was made, for the most part, at the same time with that of the vessels, as a necessary consequence of the intimate connexion which subsists between them.

After the existence of the lacteals had been clearly announced by Aselli, and of the lymphatics by Rudbek and Bartholin, the attention of anatomists was very generally directed to these organs, and discoveries were successively made, by various individuals, of the presence of the latter in almost every part of the body, and in connexion with almost every one of its organs. The labours of William and John Hunter, of Monro sec., and of Hewson, were among the most important in their results, while we are indebted to Cruikshank, and still more to Mascagni, for their minute descriptions and accurate representations of the absorbent system, in all its parts, and with its various relations and connexions.‡

* El. Phys., ii. 3. 1; Bibl. Anat., t. i. §. 378 and 415; and Not. 4. ad §. 121. Boer. Præl. Bartholin's statement of his claim is contained in his "Anat. Reform." p. 621, 2; see also his treatise, "Vas. Lymph. Hist. Nov." and Rudbek's "Nova Exerc. Anat." For the historical part of the subject we may refer to Mascagni, Prolegomena, and to Meckel, Manuel d'Anat. par Jourdan et Breschet, t. i. ch. 2. p. 179..202.

† Anat. Hepat. c. 31. See Haller, Bibl. Anat., t. i. p. 452; also Mascagni, Prolegomena.

‡ For the most original and correct description of the lacteals, the reader is referred to Haller, El. Phys. xxv. 1. 4..8; Mascagni, Vas. Lymph. Corp. Hist., p. 1. §. 7. art. 8. tab. 1. fig. 7; Sheldon, on the Absorb. Syst. ch. 2. pl. 3, 4, 5; Santorini, Tabulæ, No. 13. fig. 3; Magendie, Physiol. t. ii. p. 158..0. The translation of Mascagni's work, with copious notes by Bellini, may be advantageously consulted; it is not accompanied by plates. For the lymphatics we may refer to Haller, ii. 3. 2; Meckel, Diss. Epist. de Vasis Lymphaticis; Hewson, Enq., ch. 3. pl. 3, 6; Mascagni, ps. 1. sect. 7. tab. 4 et seq.; Cruikshank, on the Absorb., p. 148 et seq.; Sœmmering, Corp. Hum. Fabr. t. v. p. 388 et seq.; many of Mascagni's plates are transferred into Cloquet's valuable "Manuel." Art. "Inhalation," par Rullier, in Dict. des Sc. Méd. t. xxv. 3. Art. "Lymphatique," par Chaussier et Adelon, ibid, t. xxix. p. 249, 260; Meckel, Manuel, sect. 6. ch. 2; Quain's Elem. of Anat. p. 560..574. In Elliotson's Physiol. ch. 9. p. 140..2, we have a "short account of the first discovery of the absorbent system." Sœmmering's treatise, De Morbis Vasorum Absorb. contains a most ample and learned catalogue of the various works on absorption, from the earliest period to the date of its publication in 1795.

With respect to the minute anatomy of the lacteals, we are informed that they originate from certain small projecting bodies, termed villi, which are attached to the interior surface of the intestines, styled from this circumstance the villous coat. These villi are described as consisting of a number of capillary tubes, which terminate with open mouths, and that by the union of these tubes the branches of the lacteals are composed, which are sufficiently large to be visible to the eye. We must remark, however, that although these villi, as constituting the mouths of the lacteals, have been minutely described, and even figures given of the appearance which they exhibit in the microscope, yet that considerable doubt is still entertained of their existence, and that they are even entirely discredited by some anatomists of the first eminence.* Upon the whole we may conclude that the opinion, which has been generally adopted, respecting the capillary termination of the lacteals, is somewhat theoretical, rather derived from the supposed necessity of such a formation to carry on the functions of the vessels, than from any actual observations that have been made upon them.

When the lacteals have acquired sufficient magnitude to become visible to the eye, they are seen to proceed along the mesentery, the small vessels running together to form large branches, and these again forming others that are still larger, until the whole of them unite into a few main trunks, which terminate in the receptacle at the lower extremity of the thoracic duct. During their progress, the small vessels

* See Lieberkuhn, Diss. de Fabr. Vill. Intest. passim, cum tab. 1, 2; Hewson's Enq., c. 12, pt. 2; Cruikshank's letter to Clare, p. 32..4; Sheldon on the Absor. Sys., p. 32..8, tab. 1, 2; Hedwig, Disq. Ampull. In opposition to these and other authorities, on the affirmative side of the question, we have the strong negative evidence of Mascagni, whose plates do not sanction the description of Lieberkuhn, tab. 1. fig. 1. 3; and tab. 3. fig. 1, 2, 3, 5; and the decided opinion of Magendie, Journ. de Physiol. t. i. p. 3 et alibi. On this subject see the remarks of Haller, not. 9. ad §. 91. Boerhaave, Præl. et not. 4. ad §. 103. The observations of Du Vernoi, Mem. Petrop. t. i. p. 262 et seq., seem scarcely to have been confirmed.

frequently anastomose with each other, so as, in many instances, to form a complete network or plexus, in which respect their course differs from that of the veins, where the small branches unite to form the larger ones, without the lateral communications.

The lacteals are furnished with numerous valves, which are disposed in pairs, and have their convex surface turned towards the intestine,* so that, in the ordinary and healthy condition of the vessels, their contents are prevented from retrograding, and necessarily proceed from the small branches to the larger trunks. The coats of the lacteals are thin and transparent, and hence it is that these vessels, except when they are filled with chyle, are so difficult of detection. They seem, however, notwithstanding the apparent delicacy of their texture, to be possessed of considerable strength, and to bear being distended far beyond their ordinary dimensions without being ruptured. When they are completely filled with chyle, and still more, when they are forcibly distended by injections, the number of valves which they possess gives them a jointed or knotted appearance, and it seems to have been this circumstance, together with the white colour of their contents, which first attracted the notice of anatomists, and led to their discovery. With respect to their structure, besides the peritoneal covering which they possess in common with all the abdominal viscera, they seem to be composed of two distinct parts, an internal membrane, which by its duplicature forms the valves, and an external membrane, which constitutes the main substance of the vessel.

To these two obvious component parts many authors have added a muscular coat, and some anatomists of great respectability assert that they have actually detected transverse fibres, in which their contractile power is supposed to reside. Other anatomists, however, of equal authority, deny the existence of this muscular coat, and, it must be acknowledged, that the weight of the negative evidence seems to preponderate. But we may remark, on the other hand, that although these transverse fibres, constituting the muscular coat, in consequence of their transparency, or from some other cause, have hitherto eluded our observation, so that we have no positive proof of their existence, the lacteals certainly exhibit what appears to be very decided marks of contractility, and as they are not immediately connected with any organ equivalent to the heart, there seems to be no means, except their own contractility, by which their contents can be propelled.† See Chyliferous System; Lacteal.

* These were very minutely examined by Ruysch, Dilucid. Valvul., op. t. i. p. 1 . . 13; they are accurately described by Sheldon, p. 28.

† Mascagni, ps. i. sect. 4. p. 26, informs us that he could not detect the fibres; Cruikshank, on the contrary, conceives that he has seen them in the thoracic duct, p. 61 et alibi; and Sheldon speaks of the muscular coat as sufficiently obvious, p. 26. Meckel, Manuel, t. i. p. 185, does not admit their existence; and this is the case with Chaussier and Adelon, "Lymphatique," Dict. des Sc. Méd. t. xxix. p. 256. Breschet, art. "Lymphatique Systeme," Dict. de Méd. t. xiii. p. 389, considers it doubtful. Some curious observations were made by Desgenettes, on the action of the absorbents after the apparent death of the system, Journ. Méd. t. lxxxiv. p. 499 et seq. Similar observations were afterwards made by Valentin, t. lxxxvi. p. 231, et seq.; this action was not, however, supposed to depend on contractility. Wrisberg informs us that he has frequently seen spasmodic contractions in the large vessels and in the thoracic duct, Observ. Anat. Med. de Vas. Abs. Morb. in Comment. Soc. Reg. Gotting. v. ix. § 19. p. 149.

The anatomical structure of the lymphatics seems to be essentially similar to that of the lacteals; they are composed of a firm elastic membranous substance, capable of considerable distention without being ruptured, and furnished with numerous valves; like the lacteals they form very frequent anastomoses. We have the same evidence of their contractility as of that of the lacteals, although we are perhaps still less able to demonstrate the actual existence of their muscular fibres. We presume that they are likewise analogous to the lacteals in the nature of their office, and in their destination, although they differ from them with respect to their situation, or the parts of the body to which they are attached; the lacteals being confined to the membranes connected with the intestines, while the lymphatics are found in almost every part of the body, and connected with nearly all its various textures.* They differ also in the nature of the fluid which they contain, for while that of the lacteals, as has been stated above, is white and opaque, the fluid found in the lymphatics is transparent and colourless, so as to resemble water, from which they have derived their specific denomination.

It is very difficult, if not impossible, to trace the actual commencement of the lymphatics; but partly from anatomical researches, and partly from physiological considerations, we are led to conclude that they originate from the various surfaces of the body, of all descriptions, both internal and external. They resemble the lacteals, in passing from larger to smaller branches, which, after numerous anastomoses, unite in a few large trunks, the greatest part of which terminate in the thoracic duct. The great trunks of the lymphatics are, for the most part, arranged into two distinct series, one considerably more superficial than the other; it is observed that they generally follow the course of the great veins, but it may be doubted whether any direct communication

* For the extent of the lymphatic system, see Haller, El. Phys. ii. 3. 4, and the later account of M. Magendie, Physiol. t. ii. p. 174, and Jour. t. i. p. 3, who conceives that absorbent vessels have not been detected in the brain, the spine, and the organs of sense. Dr. Alison likewise conceives that they have not been detected in the cranium or nervous system, Outlines of Physiol. p. 76. Mascagni, however, appears to have detected a few small lymphatics in the brain, tab. 27. fig. 1. Monro secundus argues in favour of their existence, but it does not appear that he actually detected them in any part of the nervous system; on the Nervous System, ch. v. sect 1. and Three Treatises, ch. 4, 5.

exists between them during their course, and we are not aware of any physiological cause of this arrangement.

With respect to the mouths or origin of the lymphatics there is even more uncertainty than with respect to that of the lacteals; no anatomical investigation has hitherto been able to detect them, and although numerous facts of constant occurrence would seem to prove that their capillary extremities are distributed over all the surfaces of the body, it is from various pathological observations and from the analogy of the lacteals that we arrive at this conclusion.*

The thoracic duct is a vessel of considerable size, which is situated near the spine, and which extends from about the middle of the dorsal vertebræ to a short distance above the left subclavian vein; here it assumes an arched form, and is bent down until it enters the vessel near its junction with the jugular vein of the same side.† The duct, in its passage along the spine, is deflected in various ways, and proceeds in a somewhat irregular or tortuous course. For the most part it consists of a single trunk, but occasionally there are two trunks, either of the same or of different sizes, and we have not unfrequently partial appendages, which are added to the main trunk in different parts of its course.‡ Besides what is properly considered as the thoracic duct, in which all the lacteals and the greatest part of the lymphatics terminate, a portion of these latter, especially those which proceed from the upper part of the body and from the superior extremity of the right side, are generally collected into a separate trunk, named the great right lymphatic vessel, or right thoracic duct, which is connected with the right subclavian vein.§ These irregularities in the disposition and form of the thoracic duct may be considered as in no respect affecting its physiological uses, and to be no more than an anatomical variation of structure, probably depending upon some mechanical cause. It is, however, a circumstance of considerable importance in respect to the pathological conclusions that have been sometimes drawn from the obstructions of this organ, as well as from the experiments that have been performed upon it.* The structure and properties of the thoracic duct appear to be similar to those of the large trunks of the lacteals and lymphatics; its coats are comparatively thin and transparent, yet it is possessed of considerable strength, and is capable of being distended much beyond its ordinary bulk; it is furnished with numerous valves, and exhibits a great degree of contractility.

The lymphatic or conglobate glands† compose a very important part of the absorbent system, if we may judge from their number and their general diffusion over every part of the body. They are of various sizes, and are grouped together in various ways; occasionally they are single, but more frequently connected together in masses of considerable extent. They are found in almost every part of the body, always connected with the lacteals and lymphatics, and it is asserted that each one of these vessels, in some part of its course, passes through or is connected with one or more of these glands.‡ There are certain parts of the body in which they are more numerous, and are connected in larger masses; the lacteals are furnished with numerous glands in their passage along the mesentery, while the glands that belong to the lymphatics are found in the greatest number and largest masses in the groin, the axilla, and the neck. It is necessary to remark that this account of the distribution of the lymphatic glands applies only to the animals which belong to the class of the mammalia; in birds they are much more rare, and still more so in fish, while among the lower animals, where we have sufficient evidence of the existence of an absorbent system, the glands have not yet been satisfactorily demonstrated.§

With respect to the structure of these glands, as well as that of glands of other descriptions, a controversy has long existed among anatomists, whether they consist of a series of cells or follicles, as they have been termed, or whether they are composed simply of a congeries of vessels. The question may be regarded as still at issue; but it may be remarked that whereas the older anatomists generally leaned to the opinion of the follicular structure of the

* See Magendie, Physiol. t. ii. p. 175. Watson, however, conceived that he had detected their open mouths on the surface of the bladder, Phil. Trans. for 1769, pl. 16. Monro, in speaking of the lymphatics of fishes, remarks that there is "no doubt that they begin by open mouths," p. 30.

† For descriptions and plates of the thoracic duct the following works may be referred to; Haller, Prim. Lin. c. xxv. § 565; Op. Min. t. i. p. 586 et seq. tab. 11, 12; and El. Phys. xxv. 1. 10 . . 3: Albinus, Tab. Vas. Chylif.; Bolius and Saltzmann, in Haller, Disp. Anat. t. i.; Cheselden, Anat. pl. 26; Portal, Mém. Acad. pour 1770; Sabatier, ibid. pour 1786; Haase, De Vas. Cut. et Intest. Abs. tab. 2. and tab. 3. fig. 1; Mascagni, ps. i. sect. 7. art. 8. tab. 13, 15, 19; Sheldon, pl. 5; Cruikshank, p. 166 . . 176; Magendie, Physiol. t. ii. p. 160; Meckel, Manuel, § 1698.

‡ In Mascagni, tab. 15, we have an example of this irregularity.

§ This is said to have been discovered by Stenon in 1664; Meckel, Manuel, § 1703. See Haller, Prim. Lin. § 766 and Hewson's Enq. pt. 2. p. 61 . . 3, pl. 4. Cruikshank, p. 176, 7, conceives that Hewson was the first who described the lymphatics of the right side as being collected into one trunk. For the figure of this part, see Mascagni, tab. 19. nos. 185, 187.

* See on this subject Sir A. Cooper, in Med. Rec. and Res. p. 86 et seq., and Magendie, Journ. t. i. p. 21.

† Some of the late French physiologists prefer the term lymphatic ganglions, upon the principle that the term gland more properly belongs to an organ of secretion.

‡ Mascagni, ps. 1. sect. 4. p. 25: but this has been doubted by some anatomists; see Hewson, pt.2. p. 44, 5.

§ See Fleming's Zool. t. i. p. 338; Blumenbach's Comp. Anat. by Lawrence, ch. xiii. p. 256; Dict. des Sc. Méd. art. "Lymphatique," par Chaussier et Adelon, p. 249; Breschet, art. "Lymph. Syst.," Dict. de Méd. t. xiii. p. 397. Hewson informs us that birds have lymphatic glands in the glands,* the moderns have more frequently adopted the hypothesis of their vascular texture, so that we may consider this doctrine as supported by the most recent and elaborate researches.† See LYMPHATIC; GLAND.

§ 2. *The question of venous absorption considered.*—We have now been describing those organs, which are more specifically or appropriately termed the absorbent system, as being those parts the office of which is confined to this operation. But a very important and interesting question must now be discussed, whether the function of absorption is exclusively performed by the lacteals and the lymphatics.

The ancient anatomists and physiologists being unacquainted with the existence of the lacteals and the lymphatics, yet observing the evident effect of the operation of absorption, ascribed these effects to the action of the veins; and among the moderns, for some time after the discovery of what were more appropriately termed the absorbent vessels, it was still supposed that the veins co-operated with them, and in some cases were even the principal agents. This was the universal doctrine until the middle of the last century, and was one of the points which was decidedly maintained by Haller and his disciples.‡

The arguments by which the hypothesis of venous absorption was supported may be reduced to two classes, partly of a physiological and pathological, and partly of an anatomical nature; the first consisting of the results of experiments performed for the express purpose of investigating the subject, and of considerations derived from the morbid conditions of the system; the second depending more exclusively upon anatomical considerations. The experiments referred to consisted in passing injections from the veins to the absorbents, or the reverse, thus proving, as was supposed, that a direct connexion subsisted between these vessels. They were performed by the most skilful anatomists of the age, and were generally acquiesced in, without either the accuracy with which they were conducted, or that of the conclusions deduced from them, being ever called in question. Another class of experiments consisted in passing ligatures round the thoracic duct, so as to render it impervious to the passage of the chyle, when it was supposed that under these circumstances the nutrition of the animal was not interrupted,* and the same conclusion appeared to be substantiated by various cases of natural obstruction of the duct, or by certain malformations of the part, where it was either defective, or did not convey its contents, in the ordinary manner, into the veins. The other set of arguments, which are more purely anatomical, were derived from the supposed fact that various parts of the body, which were evidently subject to the operation of absorption, were without lymphatics, and that this was likewise the case with large classes of animals, the general structure of which, as far as regards their growth and nutrition, was analogous to that of the mammalia. Admitting these data, it seemed to be a necessary consequence that absorption must in these instances be performed by the veins, and hence it was inferred that in all classes of animals, and in all parts of the body, the veins co-operated with the lacteals and the lymphatics in the function of absorption.

The doctrine of venous absorption was first formally called in question, nearly at the same time,† by Wm. Hunter and by Monro secundus,‡ who, as it would appear, to a certain extent, entered upon the investigation independently of each other. The priority of discovery in this, as in so many points connected with anatomy, was for a long time the subject of warm controversy. We may remark concerning this question, that if the judgment of the present age should incline to ascribe to Hunter the original conception of the hypothesis, it is also disposed to allow to Monro the merit of establishing his opinion by a skilful and laborious process of experiment and observation.

The method which these illustrious rivals adopted was, first, to repeat the experiments of their predecessors, when, by noticing with scrupulous accuracy all the circumstances connected with them, they were able to demonstrate, or at least to render it highly probable, that in all those cases where injections had passed between the absorbents and the veins, either rupture or extravasation had taken place, and that, when this was carefully guarded

neck, but that they are not found connected with the absorbents of the abdomen, and that they are entirely wanting in fish and in the amphibia; Phil. Trans. for 1768, p. 217 et seq., and Enquiries, pt. ii. ch. 4, 5, 6. We have the same statement made by Monro, with respect to fish, p. 31. Antommarchi, on the contrary, asserts that birds, fish, reptiles, and amphibia have "pochissime glandule;" Prod. delle grande anat. di Mascagni, p. 8; but the statement is made in a general way, and without reference to any particular observations. It would appear that no specific apparatus for absorption has been discovered in any of the invertebrated animals.

* We have the authority of Nuck, in favour of the cellular structure, Adenologia, c. ii. p. 30 et seq., fig. 9 . . 12; also of Cruikshank, c. 14; and of Abernethy, Phil. Trans. for 1776, p. 27 et seq.

† See Hewson, v. iii. c. 2. pl. 2; Werner and Feller, Vas. Lact. and Lymph. Descript. tab. 2; their figures, however, appear to be exaggerated; Beclard, add. a Bichat, p. 231; Monro tert., Elem. v. i. p. 558. On the lymphatic glands generally see Haller, El. Phys. ii. 3. 16 . . 27; Boyer, Anat. t. iii. p. 243 . . 257; Mascagni, ps. i. sect. 5. p. 31; Rullier, ubi supra, p. 120 et seq.; Breschet, ubi supra, p. 394. For plates of the glands, see Mascagni, tab. 1. fig. 8 . . . 12, tab. 2. fig. 4 . . 8, tab. 4. fig. 2. tab. 8, 16, 26; Cruikshank, pl. 3; Sheldon, tab. 3, 5.

‡ Boerhaave, Prælect. § 103. and § 247; Haller, in not. 1. ad § 106, Boerhaave, Prælect., and not. 1. ad § 245; also El. Phys. ii. 1. 28; Monro secundus, De Ven. Lymph., p. 14 . . 21; Walter, sur la Resorption, Nouv. Mém. Berlin, pour 1786 . . 7, § 15 et seq.; Magendie, Physiol. t. ii. p. 238.

* Some experiments of this kind are referred to by M. Majendie, as having been performed by M. Dupuytren, Physiol. t. ii. p. 167. See also Richerand, Elémens de Physiologie par Berard.

† Medical Comment., passim; Cruikshank, Introd.; Walter, § 10 et seq.

‡ Dissert. de Sem. et Test. in Smellie, Thes. t. ii. and De Ven. Lymph. Valv.

against, the supposed connexion between the two sets of vessels could not be demonstrated.* In those experiments, where the thoracic duct had been artificially obstructed, or in the cases where the same thing had occurred as the result of disease or malformation, they were enabled to detect some supplementary vessels or some indirect channel, by means of which the chyle had been conveyed to the veins.

With respect to the parts of the body, or to the animals of an inferior order, which were supposed not to be furnished with absorbent vessels, by prosecuting their examination with more care they gradually detected the existence of these vessels in many cases where they had not been previously known to exist; and they were discovered in so many new situations that it became a fair inference that every part of the body, and every animal whose structure is generally analogous to that of the mammalia, is provided with an appropriate apparatus of absorption, although, from the texture or the peculiar nature of the vessels, it may be very difficult actually to demonstrate their existence. In this train of investigation the labours of William Hunter and Monro were ably seconded by various anatomists, both in this country and on the continent, among whom we may select the distinguished names of John Hunter, Hewson,† Cruikshank, and Mascagni.

* We must, however, bear in mind that we have the high authority of Meckel in favour of the communication between the lymphatics and the veins; "Sur Resorption," Nouv. Mém. Acad. Berl. ann. 1770, p. 19 et seq.

The researches of some of the most accurate among the anatomists of the present day seem also to show that occasional communications exist between some of the lymphatics and the contiguous veins; but this is a different kind of relation from that which was contemplated by the older anatomists between the sanguiferous and the absorbent systems. This point is fully discussed by Fohmann, in his late work, "Sur le commun. des vaiss. lymph. avec les veins," where we have an account of his own observations, as well as those of preceding anatomists; he conceives that the observations of Lippi, of which an account is given in his "Illustrazioni fisiol.", are not correct: see also the remarks of Antommarchi, Ann. Sc. Nat. t. xviii. p. 108, 9. The observations of Fohmann have been confirmed by Lauth, in his "Essai sur les Vaisseaux Lymph." We may here refer to the observations of Bleuland, which were made fifty years ago, on what he styles the arteriolæ lymphaticæ, by which a communication was supposed to be maintained between the sanguiferous and absorbent systems; see his "Experim. Anat." Panizza of Pavia also opposes the doctrine of Lippi; Osservazioni, c. 3 and 5. Mr. Abernethy, in examining the vascular system of the whale, discovered certain communications between the sanguiferous and the lymphatic vessels; but the nature of the connexion is perhaps a little doubtful; Phil. Trans. for 1796, p. 27 et seq. For further information on this subject, see a lecture on the lymphatic system lately published by Dr. Graves. Mr. Kiernan, in his elaborate researches into the anatomy of the liver, gives it as his opinion that the doctrine of Lippi has been "satisfactorily confuted" by Panizza; Ph. Tr. 1833, p. 729. See Elliotson's Physiol. p. 128, 9; s. 1. also a paper in Ann. Sc. Nat. t. 21. p. 252 et seq.

† Phil. Trans. for 1768 and 1769; in these volumes are contained his account of the lymphatics of birds and fishes.

The experiments of Hunter may deserve to be particularly noticed, because they consisted not merely in repeating and correcting those of preceding anatomists; but, in addition to these, he entered upon a series of original researches, which are highly characteristic of that ingenuity and acuteness for which he was so eminently distinguished. The experiments essentially consisted in filling portions of the small intestines with a fluid, the sensible properties of which might be easily recognized, and retaining it there so as to allow of its entering into the veins of the mesentery, were they capable of absorbing it; the result, however, is stated to have been that in no instance could the fluid be detected in these veins. These experiments appeared to have been so carefully conducted, and so frequently repeated, as to have impressed the minds of anatomists and physiologists with a conviction that the lacteals were the only vessels which are concerned in the absorption of the chyle; and although it was not possible to perform analogous experiments on the lymphatics, yet it seemed a natural inference, that we might extend to them the conclusion which had been established with respect to the lacteals.*

In proof of lymphatic absorption various facts were brought forward, which seemed clearly to show that when extraneous or noxious substances were introduced into the system, it was done by the medium of the lymphatic vessels rather than of the veins; and it was thence argued that, as these vessels perform the function of absorption under certain circumstances, and that we are not acquainted with any other office which they serve in the system, we may conclude that they are the sole agents in the action of absorption. Although the argument, as applied to the lymphatics, was far less direct and conclusive than to the lacteals, yet the analogy between the two organs appeared so strong, and so many concurring circumstances appeared to favour the doctrine, that it was very generally received, and may be considered as having been the established opinion at the conclusion of the last century.†

This unanimity of opinion was, however, of very short duration; for anatomists had scarcely ceased to contend for the honour of the discovery of the exclusive action of the lacteals and the lymphatics in the function of absorption, when the doctrine itself was impugned by physiologists of the first eminence, who supported their views by a powerful train of arguments, enforced by numerous experiments,

* Med. Comment. c. 5 p. 42..8; Cruikshank, c. 5. p. 21.

† See the judicious summary of opinions in Mascagni, ps. i. sect. 2, 3: and in Rullier, ubi supra, p. 136 et seq. The doctrine of venous absorption was, however, still maintained by many intelligent anatomists, especially by the high authority of Meckel, De Fin. Ven. et Vas. Lymph. 1772; and of Walter, Sur la Resorption, ubi supra. See particularly his general conclusion, § 92: he conceives that the veins are the only agents in the absorption which is carried on at the surface and from the cavities of the body.

and by various pathological considerations. Of these authors, one of the first, both in point of time and of ability, is M. Magendie, whose opinions on this subject, connected as as they are with some of those of his most distinguished countrymen, have been brought forward in a form which entitles them to the fullest and most respectful attention.

Of the two sets of observations by which Hunter and Monro attempted to establish their hypothesis respecting lymphatic absorption, those derived from the analogy of the lacteals may still be considered as maintaining their ground; while the conclusion which they deduced from their experiments has been called in question, partly because it was thought not to be the legitimate inference from the experiments, and partly in consequence of the experiments themselves having been conceived to be imperfect or incorrect. It is principally upon the latter ground that the force of the objections has been rested; and it has been, first, by repeating the experiments of Hunter, and afterwards by varying them in different ways, that their insuffficency has been attempted to be proved. It has been stated above that the main support of the doctrine of the exclusive action of the lacteals and the lymphatics was derived from those experiments of Hunter, in which it appeared that, when the circumstances were the most favourable for the reception of substances into the veins of the mesentery, they could not be proved to have entered these vessels; and hence it was concluded that the veins did not, under any circumstances, possess the power of absorption.

We are informed, however, by M. Magendie that experiments have been performed by himself and by M. Flandrin, which afforded directly contrary results, and that these experiments were so frequently repeated, and varied in such a manner, as to leave no doubt of their accuracy.* We have here the opposing testimony of individuals, both of them of the highest authority in science, and eminent for their skill in experimental research. From personal considerations it might be difficult, if not impossible, to decide between them; but when we take into account the circumstance that the experiments of MM. Magendie and Flandrin were executed subsequently to those of Hunter, and with the benefit of his experience and that of the improved state of the science during the last half century; when, moreover, we are informed that the experiments of the French physiologists were more numerous than those to which they were opposed, and that their results were uniform and unequivocal, we can scarcely refuse our assent to the conclusion, that the experiments of John Hunter do not afford a sufficient foundation for the doctrine of the non-absorption of the veins.

But the French physiologists have not satisfied themselves with repeating the experiments of Hunter; they have extended them in various ways, and have obtained results supposed to be still more decisive in favour of venous absorption. Among the most important, or at least the most curious of these, is an experiment which was performed by M. Magendie, in conjunction with M. Delille, and which was conceived by these physiologists to afford the most unequivocal proof of their hypothesis. It consisted in dividing all the parts of one of the posterior extremities of a living animal except the artery and the vein, and in applying to the foot a poisonous substance; when, in the short space of a few minutes, the effects of the poison on the functions of the animal were most distinctly apparent.* It was argued that in this case there was no mode of communication by which the poison could be conveyed from the extremity to the centre of the system except the vein, and that, therefore, the vein must have acted as the absorbing vessel. The experiment was rendered more striking, and, as was conceived, more conclusive, by dividing the bloodvessels themselves and introducing metallic tubes between the divided ends, through which alone the two currents of the arterial and venous blood respectively could pass in forming the communication between the extremity and the trunk of the animal, yet, under these apparently unfavourable circumstances, the deleterious effects were manifested on the system as in the former case.† Experiments of this description appear to have been sufficiently multiplied to establish the fact, that the poison in these cases passed along the vein, and was conveyed in the general mass of the blood.

The result of these experiments is no doubt very remarkable, and what would scarcely have been anticipated; yet we may remark, that there is one circumstance connected with them, which, in a great measure, invalidates the conclusion that has been supposed to follow so necessarily from them. It may be inferred from the expression made use of, that the poison employed, which was the extract of the upas tree, was inserted by a puncture or incision into the foot of the animal, and would, therefore, in the first instance, be mixed with the blood; so that the only deduction which we are warranted to draw from the experiment is, that the venous blood, being infected with the poison, had the power of communicating the infection to the system at large.‡ On this view of the subject we should not regard the above as a case of absorption, but merely as an instance of the power of extraneous substances, under certain circumstances, of uniting with the venous blood and retaining their specific properties.

In connexion with these experiments of M. Magendie and his associates, we have another series which were performed by MM. Tiedemann and Gmelin, and which bear directly upon the question of venous absorption. Their object was to ascertain whether there

* Physiol. t. ii. p. 181 et seq.; Journ. Méd. t. lxxxv. p. 372 et seq., and t. lxxxvii. p. 221. et seq., and t. cx. p. 73 et seq.

* Magendie, Journ. t. i. p. 25..7.

† Journ. t. i. p. 23 et seq.; Elem. t. ii. p. 183..5.

‡ See Rullier, ubi supra, p. 150..2: and Adelon, "Absorption," Dict. de Méd. t. i. p. 148.

was any direct communication between the organs of digestion and the bloodvessels except by means of the lacteals. For this purpose they mixed with the food of an animal various substances, which by their colour, odour, or other sensible and physical properties, might be easily detected in the fluids of the body. After some time the animal was examined, and the result was that unequivocal traces of the substances were not unfrequently detected in the venous blood and in the urine, while it was only in a very few instances that any indicatiou of them could be discovered in the chyle. The colouring matters employed were various vegetable substances, such as gamboge, madder, and rhubarb; the odorous substances were camphor, musk, assafœtida, &c.; while, in other cases, various saline bodies, such as muriate of barytes, acetate of lead and of mercury, and some of the prussiates, which might be easily detected by chemical tests, were mixed with the food. The colouring matters, for the most part, were carried out of the system without being received either into the veins or the lacteals; the odorous substances were generally detected in the venous blood and in the urine, but not in the chyle, while of the saline substances many were found in the blood and in the urine, and a very few only in the chyle.*

The conclusion, which we are disposed to regard as the fair inference, from the facts and arguments that have been adduced on the subject of venous absorption, is that, although there are strong analogies and various pathological considerations which would induce us to confine the function of absorption to the lacteals and the lymphatics, yet that the result of the experiments, although not uniform, is upon the whole in favour of venous absorption. It only remains for us to inquire how far the state and actions of the parts on which the experiments were made, were so far necessarily deranged by the process to which they were subjected as to render the results inapplicable to the natural condition of these organs. Now this certainly appears to be the case in the experiments of MM. Magendie and Delille, where the poisonous substance was introduced into the blood; and the same remark may probably be applied to a number of pathological occurrences that have been supposed to afford a proof of venous absorption, such, for example, as the case of ulcerated surfaces, where pus has been detected in the veins, and still more extraneous bodies, which may have been either accidentally or designedly inserted into the ulcerated part.† But it is not unreasonable to suppose that in these instances, in consequence of the erosion and partial destruction of the organs, the small branches of the veins will present an external orifice, through which the pus or other extraneous substance may be immediately received into the sanguiferous system, nearly upon the same principle as in the experiments related above.

The experiments of MM. Magendie and Flandrin, the results of which were so opposite to those of Hunter, do not indeed lie open to the same objection; but even here there is perhaps some ground for inquiry, before we implicitly adopt the conclusion that has been deduced from them. The experiment, as originally performed by Hunter, necessarily implies a degree of mechanical violence, which must produce a considerable derangement of the actions of the parts concerned. Acute inflammation of a peculiarly irritable and sensitive organ must have ensued, the vessels of all descriptions must have become much distended; rupture and extravasation may have been not an improbable consequence of this inflammation and distention, and, in short, a general derangement both of structure and functions may have occurred, which must prevent us from drawing any positive inference respecting their natural condition.

These observations will apply with much greater force to a subsequent variation of the experiment, which consisted in entirely detaching a portion of the intestine from the remainder of the tube, and filling this divided portion with the fluid, which, as in the former case, was detected in the vein of the mesentery. This arrangement was supposed to afford a still more decisive proof of venous absorption than the experiment in its original state, and if we consider the mechanical disposition of the organ only, we may admit that this would be the case. But it is obvious, on the other hand, that the vital actions of all the parts concerned must have been much more deranged, and that, on this account, we ought to be proportionally cautious in the application of such experiments to our physiological theories.

We would venture to suggest, that the remarkable discrepancy which exists between the experiments of Hunter and of the French physiologists may perhaps be reconciled, by having recourse to the supposition, that in the former case there was less violence used to the parts, and that they were left more in their natural condition; whereas M. Magendie, as we presume, from a desire to render the effect more certain or more decisive, either produced a greater degree of distention of the intestines, or, in some other way, caused a greater derangement of the parts, so as to produce a difference in the results. But this idea is offered merely as a conjecture, from which we do not venture to deduce any of our conclusions.

Upon the whole we feel disposed to regard the experiments of MM. Tiedemann and Gmelin, and those of an analogous kind, in which extraneous substances were found in the venous blood, and in some of the secretions, when they could not be detected in the chyle, as more directly

* Ed. Med. Journ. vol. xvii. p. 455 et seq. On the absorption of foreign bodies see the early experiments of Lister and Musgrave, Ph. Trans. for 1683 and 1701; also Lowthorp's Abrid. vol. iii. p. 101 . . 5, and La Motte's Abrid. par. 2. ch. iv. p. 75, 6; with Haller's sanction of their accuracy, El. Phys. xxiv. 2. 3; see also J. Hunter, in Med. Com. p. 44 et seq., and Cruickshank, ch. viii. On the other hand, the experiments of M. Magendie and his friends would lead us to form an opposite conclusion; Elem. t. ii. p. 168, 9. See Elliotson's Physiol. p. 126.

† See the experiments of Mr. Key, in Med. Chir. Trans. vol. xviii. p. 212, 13.

favouring the doctrine of venous absorption, because they are free from the objection which must always attach to those operations, where any considerable degree of mechanical violence has been employed. It may indeed be objected, that in these cases, the examination of the body did not take place at the proper point of time; that, in some instances, it was made at too early a period, before the extraneous body had time to enter the lacteals, and, in other cases, not until it had left them, and had been discharged from the thoracic duct into the veins. But this contingency must be regarded as rather a possible than a probable occurrence, and it is obvious that if any considerable number of experiments were performed, we can scarcely suppose it to exist.

The conclusion that we are disposed to draw from all the facts and arguments that have been brought forwards on the subject is in favour of the possibility of venous absorption, at least under peculiar circumstances; at the same time that there are strong anatomical considerations, which would induce us to suppose, that in the ordinary actions of the system, the function of absorption is confined to the lacteals and the lymphatics.*

§. 3. *Inquiry into the mode in which the absorbents act.*—In entering upon this inquiry there are two distinct subjects which present themselves for our consideration; we must first ascertain by what means the substances that are absorbed enter the mouths of the vessels, and, in the second place, after they have entered the mouths, how they are conveyed along the vessels themselves.

With regard to the first of these points we may remark, that while there is so much uncertainty respecting the anatomical and physiological structure of the mouths of the lacteals, and still more, while we are completely ignorant of that of the lymphatics, we cannot expect to arrive at any definite conclusion concerning the mode of their action. We may, however, venture to say, that there is strong reason to believe, that the absorbents terminate in very minute or capillary vessels, that have open mouths, and that these mouths are brought into contact or close approximation with the substances to be absorbed. Hence, by an analogy, which it must be acknowledged is somewhat vague, the action of these minute vessels has been referred to capillary attraction. But it may be doubted whether in this inference, as in so many other cases of physiology, we have not been misled by a mere nominal resemblance, and have applied the term capillary to the action of the lacteals, because it had been used to denote their dimensions. Perhaps, strictly speaking, there is scarcely a single circumstance, in which the action of the lacteals can be assimilated to that by which fluids are taken up by capillary tubes. The structure and consistence of the tube itself, the nature of the substance on which it is supposed to act, and their relative situation, are all of them more or less different from what occurs in the ordinary cases of capillary attraction. And if there is a difficulty with respect to the lacteals, where we have at least some indistinct evidence of the mechanical disposition of the parts, which may seem favourable to this hypothesis, in a much greater degree will it exist with respect to the lymphatics, where we have nothing to direct our opinion, except the analogy which may be presumed to exist between the two species of absorbent vessels.

In consequence of these difficulties, and of the supposed inadequacy of the mechanical theory, many physiologists have had recourse to a certain specific action of the vessels, and have conceived that the chyle was taken up by a power, which has been supposed to be analogous to an elective attraction between the vessel and the substance that is absorbed.* There are indeed many circumstances which would appear to indicate, that a certain kind of selection is exercised by the mouths of the vessels, for, as far as we are capable of judging, when substances possessed of the same consistence and physical properties are placed in contact with these mouths, some of them are received, while others are rejected. But we must remark, that the same objection may be urged against this as against the former explanation, that the term elective, which is borrowed from the chemical relation of bodies to each other, is perhaps as little applicable to the case under consideration as that of capillary, which refers more to their mechanical action.

Discarding therefore all these analogical illustrations, which are at least of doubtful application, we may remark, that the lacteals ought to be regarded, like every other part of the animal frame, as vital organs, possessed of appropriate and specific powers; that, in this instance, we are not able to refer to any general principle the train of events now under consideration, and that we must therefore be satisfied with simply stating the fact, that the lacteals have the power of taking up by their extremities certain substances, with which they are in close approximation; that, for the most part, the substances which they receive are the elements of the chyle, that they select these from the contents of the intestinal canal, and

* A summary of M. Magendie's experiments and deductions is contained in his Journ. t. i. p. 18 et seq. and his Elem. t. ii. 238 . . 243; on this subject see also Bichat, Anat. Gén. t. ii. 104, 5, with the remarks of Beclard, p. 130. We must not omit to notice the experiments of M. Ségalas, who by dividing the bloodvessels of a portion of the intestine, and leaving the lacteals, thus, as it were, reversing the experiments of M. Magendie, found that no absorption took place, and hence concludes that the lacteals do not possess this power; Magendie's Journal, t. ii. p. 117 et seq. So singular a conclusion must, we conceive, lead us to place but little confidence in the result of such complicated experiments. Franchini of Bologna thought that the lymphatics absorb "la sostanza assimilabile," but that the substances which do not directly contribute to nutrition are absorbed by the veins; Consider. Fisiol. sull' Assorb. p. 44.

* See Bichat, Anat. Gén. t. ii. p. 125; Dumas, Physiol. t. ii. p. 397, 8; Young's Med. Lit. p. 112; Bell's Anat. v. iv. p. 290. M. Magendie, however, is disposed to reject all these hypothetical explanations; Elem. t. ii. p. 162, 3, and Journ. t. i. p. 3. et alibi.

that, except under peculiar circumstances, they reject every other substance.*

When the elements of the chyle have been received into the lacteals, it appears to undergo a certain degree of elaboration, by which it is farther assimilated and perfected, an operation, the intimate nature of which we are unable to explain, but which, as well as its entrance into the mouths of the vessels, we correctly refer to their vital action. After the chyle has entered the lacteals, there is less difficulty in conceiving the subsequent steps of the process. We are at least able to generalize the operation, by referring it to contractility, the same power which originates motion in other parts of the system. It must, no doubt, be admitted, that the existence of the muscular fibres of the lacteals has not beeu satisfactorily demonstrated, and that, until this has been accomplished, our opinion can only be regarded as hypothetieal : but we have here the advantage of being able to assign a probable and sufficient cause of the effect, and are aware of the point towards which we must direct our future investigations.† Before we conclude this branch of the subject, we may remark concerning the contents of the lacteals, that, under ordinary circumstances, we have no decided proof of these vessels containing any substance except the elements of the chyle, and that, although in some of the experiments referred to above, extraneous bodies have been occasionally found in them in minute quantity, these cases must be regarded as exceptions to the general fact.

With respect to the ehyle itself, it has been a subject of examination by the chemists, whether its properties are always uniform in the same animal, or class of animals, under the various circumstances of age, constitution, and still more of diet, to which they are subject. But it may be necessary, before we enter upon this inquiry, to premise a few remarks upon the meaning of the terms chyme and chyle. By the older physiologists they were very generally employed as synonymous, and this is still the case with some of the modern writers, more especially on the continent.‡ A clear distinction between them has, however, been pointed out and recognized, and as there appears to be an essential difference between them, it is desirable that it should be generally adopted. The first of these substances is the immediate product of the action of the gastric juice on the aliment, as received into the proper digestive stomach, while the latter is the substance which is produced by a subsequent part of the process of digestion. The conversion of ehyme into chyle seems to commence shortly after it leaves the stomach, and while it still remains in the duodenum, is so far advanced as to be reduced into a condition proper for being received into the lacteals. There is, however, reason to believe that the completion of the process takes place in the lacteals themselves, and even that it is not until the chyle arrives at the thoracic duct, or at least at the great trunks of the lacteals, that it is fully elaborated. The nature of the change which the chyme experiences in the duodenum, and the agents by which this change is effected, what share the secretions of the part itself, the bile, or the pancreatic juice have in the operation, are questions that still remain in discussion, and which will be considered in the appropriate parts of this work.*

For the analysis of the chyle we are prineipally indebted to Vauquelin, Marcet, and to Dr. Prout. Vauquelin employed the chyle of the horse, as taken from the large trunks of the lacteals and from the thoracic duct.† The experiments of Marcet were principally directed to the inquiry, how far the chyle of the same kind of animal was affected by differences in the diet, according as it consisted principally of animal or vegetable substances.‡ Dr. Prout's experiments on the chyle extended both to its general properties, and to the differences produced by different kinds of diet, while, in addition to these points, he entered into a very interesting examination of the successive changes which it experiences, from its first entrance into the lacteals until its final deposition in the thoracic duct.§ The result of these experiments, as far as our present inquiry is concerned, tends to shew that the vegetable chyle differs somewhat, in its physical and ehemical properties, from that of animal origin, and that the chyle, when it first enters the lacteals, is in a less perfect state, while it becomes more assimilated to the blood in proportion as it advances towards the thoracic duct.

With respect to the means by which the animalization of the chyle is perfected after it enters the vessels, we have no certain information, and we have scarcely any analogy which may assist in guiding our opinion. What is termed by modern physiologists the action of the vessels, by which so many operations of the animal economy are supposed to be effeeted, we may regard rather as an expression which serves as a convenient veil for our ignorance, than as throwing any light upon the process. We have no evidence that any addition is made to the chyle while in the lacteals ; and indeed we can scarcely suppose it possible that this is the case, so that the only conceivable effect of this action is reduced to the motion which is imparted to the chyle by the alternate contraction and relaxation of the vessels, in conse-

* See the remarks of MM. Chaussier and Adelon, ubi supra, p. 272 et seq. ; also Adelon, Physiol. t. iii. p. 85 et seq. ; and Alison's Outlines, p. 79.

† This is essentially the doctrine of Haller, Prim. Lin. c. xxv. §. 568. Sheldon, p. 28, and Cruikshank, c. 12, are advocates for this doctrine ; but it is opposed by the high authority of Mascagni, ps. i. sect. 4. p. 27, 8.

‡ This appears to be the case with M. Rullier, art. "Chyme," in Dict. de Méd. t. v. p. 241 . . 4 ; M. Adelon, however, clearly marks the distinction, Physiol. t. iii. p. 25, et alibi.

* See the remarks of Adelon, art. "Chylifères," Dict. de Méd. t. v.

† Ann. Chim. t. lxxxi. p. 113 et seq. ; Ann. Phil. v. ii. p. 220 et seq.

‡ Med. Chir. Trans. v. vi. p. 618 et seq.

§ Ann. Phil. v. xiii. p. 22 . . 5.

quence of which the constituents may be more completely mixed together, and to a certain degree of pressure and temperature to which it is exposed, which may modify any spontaneous change that might otherwise take place in the arrangement of its elements. But to whatever cause it may be referred, we must consider the chemical and physical change in the nature of the chyle as one effect produced by the lacteals, as well as the progressive motion which is imparted to their contents.

In the present state of our knowledge on the subject, it remains for us to consider whether we have any independent evidence of the existence of the muscular fibres of the absorbent vessels, whether, if their existence be proved, and their contractility thus established, it would be necessary for us to search out for other causes of the effects, and lastly, to what other principle the acknowledged effects might be attributed, should it appear, upon full consideration, that the assigned cause is insufficient or inadequate.

The above considerations lead us to give an account of the hypothesis of the action of the absorbents, which has been proposed by M. Magendie. He had ascertained, by a previous train of experiments, that according to the condition of the system as to depletion or plethora, the process of absorption was respectively accelerated or retarded. Hence he draws the conclusion, which, however, we conceive not to be a necessary consequence of the premises, that the function depends on a mere mechanical principle, independent of any vital action. The mechanical principle to which he has recourse, and which he thinks can alone account for the effect, is that of capillary attraction; but this he conceives not to take place from the open mouths of the vessels, according to the ordinary conception of the subject, but that the fluid is imbibed by the substance of the vessel itself, and is, as it were, filtered through its pores.* He explains its further progress by supposing, that when it has entered these pores, it is carried forwards by the current of the fluid previously in the vessel.

To prove his idea of the permeability of the parietes of the vessels, he instituted a series of experiments on the veins of an animal shortly after death, when he found that they were capable of imbibing and transmitting certain fluids with which they were placed in contact. Still farther to substantiate the hypothesis, M. Magendie repeated a set of analogous experiments on the vessels of a living animal. They consisted essentially in detaching a portion of one of the great veins, and applying to its surface the solution of some narcotic or poisonous substance, the effects of which were, in a short time, manifested in the system at large.*

This doctrine of imbibition and transudation has been embraced by M. Fodéra, who has endeavoured to confirm the opinion of M. Magendie by additional experiments, which he conceives tend directly to prove that the vessels of the living body possess this power of imbibition. The method which he adopted to prove this point, in the most unequivocal manner, was to inject into two separate cavities of the body two fluids, which by their union produce a compound, the presence of which may be easily detected, and which could be formed by no other means except by this union. For example, into the cavities of the pleura and the peritoneum were respectively injected the solutions of the ferro-prussiate of potash and of the sulphate of iron, when it was found, after a certain length of time, that various membranes and glands, connected with the thorax and the abdomen, were tinged with a blue colour.

M. Magendie afterwards performed an experiment, which seemed more directly to bear upon the question, where a solution of the ferro-prussiate was retained in a portion of the intestine, at the same time that its external surface was placed in contact with a solution of the sulphate of iron: the part was then exposed to the galvanic influence, the result of which was that a blue tinge was communicated to the sulphate. We are further informed, that according to the direction of the galvanic current, the blue colour was produced either in the sulphate or in the ferro-prussiate. From these experiments M. Fodéra draws the conclusion, that the processes of absorption and of exhalation may be referred to the mechanical operations of imbibition and transudation, which take place through the pores or capillary openings of the various textures of the body.†

On these experiments, and the conclusion deduced from them, we shall remark, that the facts appear to prove that membranes, perhaps during life, and certainly after death, before any visible decomposition has taken place, are capable of transmitting fluids through their texture; but we conceive that the analogy between this case and that of the entrance of chyle into the lacteals is so incomplete, that we can draw no inference from the one of these events which can be fairly applied to the other. Both the mechanical and the physiological properties of membranes and vessels differ much from each other, while the nature of the fluids employed in

* Journ. t. i. p. 6 et seq. and Dict. de Méd. et Chir. Prat. "Absorption," t. i. p. 91 et seq. The doctrine of transudation was maintained by many of the older physiologists; see Kauw Boerhaave, de Persp.; also Haller, El. Phys. ii. 2. 23; more lately it was supported by W. Hunter, Med. Com. ch. 5; by Walter, ubi supra, § 28 . . 35; and by Mascagni, ps. 1. sect. i. and is zealously maintained by his commentator Bellini, t. i. not. 4. p. 33 . . 6. The "pénétrabilité" of the cellular texture was one of the fundamental doctrines of Bordeu, Recherches sur le Tissue muqueux, § 72.

* Journ. t. i. p. 9, 10.

† "Recherches sur l'Absorption et l'Exhalation," and Magendie's Journ. t. iii. p. 35 et seq.; see, also Med. Repos. v. xix. p. 419, et Med. Journ. v. xix, p. 488, 9. On this subject see the remarks of Tiedemann, Traité de Physiol. par Jourdan, § 168. p. 242. Mr. Mayo remarks, that the principle of imbibition and transudation affords a more easy explanation of the experiments of MM. Magendie and Ségalas, than that of venous absorption; Physiol. (3rd ed.) p. 97 et seq. See the remarks and objections of Sir D. Barry, Exper. Researches, p. 80 . . 2 et alibi; also Elliotson's Physiol. p. 133.

the experiments is totally different from any thing to which the parts are exposed under ordinary circumstances. It may be further remarked, that if the texture of the vessels is so permeable to fluids of all kinds and in all directions, it is difficult to conceive of any cause which can retain them there when they have entered, and which should prevent their escaping through the same pores when any pressure is made on the contents of the vessels by its contractile power or by any extraneous force.

And it may be further remarked concerning these experiments, without impugning the accuracy or the dexterity of the operator, that they imply a degree of minuteness in the execution, and of attention to a variety of concurrent circumstances, and are altogether of so extremely delicate a nature, as to render it undesirable that any physiological conclusion should be founded on them. If a single bloodvessel be divided, however minute, and its extremity be exposed, or even if a single cell of the membranous texture be laid open, so as to admit of the introduction of the fluid, the essence of the experiment is destroyed, and its results must become equivocal.

Another hypothesis respecting the nature of absorption has been lately brought forward by Sir D. Barry, according to which it immediately depends on atmospheric pressure, either exercised directly on the surface of the body, or acting indirectly on the absorbents through the medium of the great internal cavities. The experiments on which the hypothesis rests consisted in introducing a portion of some poisonous substance into a wound, and forming a vacuum over it by means of a cupping-glass; when, by contrasting the effect of the poison in this case with that which ensues from the same application where the cupping-glass was not employed, he concludes that the process of absorption was suspended by removing the atmospheric pressure, and he hence infers that this pressure is the cause of absorption.*

The results of these experiments, in a practical point of view, are of great interest, but with respect to the physiological conclusion that has been drawn from them, there are various circumstances to be taken into account, which appear not to have been duly attended to.

In the first place, a similar kind of objection occurs in this case as in the experiments of MM. Magendie and Delille related above, that the poison was introduced into a wounded part, and would therefore be immediately mixed with the blood and carried into the general circulation. The effect of a vacuum formed over the divided extremity of a vessel, must be to retard the progress of its contents, whatever be its description, or in whatever cause it originates. This effect is therefore not specifically applicable to absorption, even in the natural state of the parts; and when we consider that in this case there was an artificial opening made into the vessel, we may venture to affirm that the conclusion which was drawn from it is in no respect the necessary inference from the facts.

* Barry's Exper. Researches, pt. 2 "On Absorption;" Alison's Outlines, p. 85; Bostock's Physiol. v. ii. p. 593 et seq.

And besides this general objection, it may be fairly questioned how far the removal of pressure from the surface of the body could act in retarding the progress of a fluid along a vessel which has no external opening, and which is provided with valves, such as is strictly the case with the lacteals, and may be almost said to be so with the lymphatics. And with respect to the lacteals, it appears a very obvious objection to the hypothesis, that they are altogether defended from the effects of atmospheric pressure, either as applied directly, or as indirectly acting on them through the medium of any of the internal cavities. Besides, we have sufficient proof of the spontaneous and independent action of these vessels, whatever may be our opinion respecting the existence of their muscular coat, and to whatever principle we may refer this action, and we have thus an actual cause for the propulsion of their contents, although it is impossible to estimate its actual amount, it would appear unnecessary to search for any farther agent, unless we have good ground for concluding that the existing cause is inadequate to produce the effect required.

Cutaneous absorption.—There is a branch of the subject to which we must now direct our inquiry, the existence and extent of what has been termed cutaneous absorption. When we trace the progress of the lymphatic vessels from their great central trunks, and follow them through all their minute ramifications, we find that many of them appear to have their origin from the surface of the body,* and hence we are led to suppose that the function of absorption is exercised, to a certain extent, by the cutis, or the parts immediately connected with it. That this is the case is proved by various pathological facts; we have daily opportunities of observing, that various medicinal substances, by mere application to the surface, and still more when aided by friction, produce the same effect upon the system as if they had been received, in the ordinary way, through the medium of the stomach. By this means mercury manifests its specific action on the salivary glands, the salts of lead destroy the contractility of the muscular fibre, while opium, tobacco, and other narcotics produce their peculiar effects on the nervous system.

But, besides this kind of absorption, which is brought about by the substances being, as it were, mechanically forced into the pores of the skin, and thus applied to the mouths of the lymphatics, it was an opinion very generally embraced by the older physiologists, and still retained by many of our contemporaries, that the lymphatics, which are distributed over the surface, possess the power of imbibing water, when simply applied to it by the immersion of the body, or even when it is exposed to

* See Haase, De Vas. Cut. et Intest. Absorb., tab. fig. 2; also, Mascagni, tab. 2. fig. 9..28, tab. 3.

aqueous vapour diffused through the atmosphere. This supposed power of cutaneous absorption was called in to account for various physiological or pathological facts, for which it appeared to afford a plausible explanation, while, on the other hand, the easy mode in which it appeared to account for these facts was made use of as the great argument to prove its existence. The statical experiments of Sanctorius, which have, since his time, been so much multiplied and extended, were supposed to prove unequivocally that the body is capable of gaining weight independently of any substance received into the stomach, and to account for this addition, recourse was always had to the cutaneous absorption. Of late, indeed, it has been discovered, that a part of the effect ascribed by Sanctorius to the action of the skin is in reality due to the lungs, but still, after making the necessary deduction for the operation of the latter organ, there remained a certain increase of weight, which it was supposed could only be accounted for by admitting the existence of the cutaneous absorption.*

The doctrine of cutaneous absorption has, however, been altogether called in question by Seguin, who performed a series of experiments, which consisted in immersing a part of the body in a saline solution, for example, that of corrosive sublimate, the effects of which on the system at large would be easily recognized, if any part had been absorbed. The result was, that when the cuticle was entire, no effect that could be attributed to absorption took place, and the conclusion seemed not unnatural, that under ordinary circumstances it did not exist.† Currie was led to form the same conclusion by accurately weighing the body before and after immersion in the warm bath, under circumstances which were conceived to be favourable to the process,‡ and as the results of his experiments coincided with those of Seguin and others, the doctrine of cutaneous absorption, except under the particular circumstances mentioned above, was very generally abandoned. Experiments have been adduced to prove, that even under these particular circumstances, when substances are applied by friction to the surface, they do not enter into the mouths of the vessels, but being volatilized by the heat of the body, that the vapour thus produced is inhaled by the lungs;§ an opinion which one might be inclined to think was almost too extravagant to be seriously maintained.

The subject of cutaneous absorption has been lately investigated by Dr. Edwards, with that skill and address which he has applied to so many departments of physiology. By a number of experiments, which were performed on cold-blooded animals, where it was more easy to observe the effects, he found that absorption was carried on, to a considerable extent, when the animal, or a part of it was immersed in water. The conclusion which the experiments seemed to warrant was, that transudation and absorption are, at all times, going forwards at the surface, but that the operations proceed at different rates, according to the circumstances in which the animal is placed, and that the body gains or loses weight, in proportion to the excess of one of them above the other. The analogy of the cold-blooded animals he applies to those with warm blood, and he supposes that they are subject to the same double action, a conclusion which appears to be confirmed by some experiments that were performed on guinea-pigs immersed in moist air, when an increase of weight was found to have taken place, which, after taking every circumstance into consideration, seemed necessarily to depend on absorption.* With respect to the experiments of Seguin, Dr. Edwards is not disposed to call their accuracy in question, but he points out various circumstances connected with them, which he conceives would tend to increase the transudation, and to diminish, or even entirely to suspend the absorption.† The experiments of Dr. Edwards, considered in all their relations, are generally conceived to decide the question respecting the existence of cutaneous absorption, under the ordinary circumstances, and in the natural conditions of the system.

§. 4. *Of the specific uses of the different parts of the absorbent system, and of the relation which that system bears to the other vital functions.*—Whatever opinion we may form on the controverted question respecting venous absorption, and in whatever manner we may explain the action of the lacteals and the lymphatics, there can be no doubt that their specific use is to absorb certain substances which are presented to their extremities.‡ There is, however, so well marked a distinction between the situation and the anatomical relations of these two kinds of vessels, as well as between the substances that are found to be contained

* Mascagni, p. 22, 3; see also Kellie, in Ed. Med. Journ. v. i. p. 170 et seq.; and the article "Integuments" in Rees's Cyclop.

† Fourcroy, Méd. Eclair. t. iii. p. 232 . . 241, and Ann. Chim. t. xc. p. 185 et seq.

‡ Med. Reports, ch. xix.

§ Ed. Med. Journ. v. ii. p. 10 et seq.

* De l'Influence des Agens, &c. ch. xii. p. 345 et seq.

† De l'Influence, &c. ch. xiii. p. 556 et seq. See on this subject, Magendie, Physiol. t. ii. p. 189 . . 196, and Dict. de Méd. et Chir. Prat. "Absorption;" where he endeavours to prove, that it is the veins and not the lymphatics which are the agents in cutaneous absorption. See also the remarks of M. Rullier, ch. ii.; and of M. Adelon, Physiol. t. iii. p. 10 et seq.; also art. "Absorption," Dict. de Méd. t. i. p. 124 et seq. M. Chaussier found that sulphuretted hydrogen gas, when applied to the surface of the body, manifested its deleterious effects on the system, Bibl. Méd. t. i. We have already had occasion to notice the opinion of Walter on this subject, p. 25, which is similar to that of M. Magendie. M. Buisson attempts to establish a distinction between the absorption which is carried on by the membranes and by the cellular texture, De la Divis. des Physiol. Phenom. p. 251 et seq.

‡ M. Magendie indeed doubts this position so far as the lymphatics are concerned; Journ. Physiol. t. i. p. 18 et seq. and Physiol. t. ii. p. 238 . . 243.

in them, that we are naturally led to conclude, that they are destined for different uses, and serve different purposes in the animal economy. With regard to the lacteals, their use seems to be clearly marked by their connexion with the digestive organs, and by their contents, as constituting the channel by which the chyle is conveyed from the intestines to the thoracic duct, and ultimately to the bloodvessels. We cannot doubt that their primary function is to supply the body with the elements which compose the blood, and thus become the immediate agents in its nutrition. Although, from the experiments which have been related above, it will appear that, on certain occasions, the lacteals are not incapable of receiving extraneous bodies, yet we may conclude, that this is the case only under extraordinary circumstances, or in an unnatural state of the parts.

With respect to the lymphatics, their specific use is less obvious. As their contents are ultimately mixed with those of the lacteals, we may suppose that they contribute indirectly to the nutrition of the body; but this would appear not to be their primary, or even their principal destination. Still we can scarcely refuse our assent to the position, that absorption is the specific function of the lymphatics; and this will be equally the case, although we may suppose that the veins cooperate with them in this action.

We are indebted to the genius of John Hunter for a consistent or plausible theory of the use of the lymphatics, which, with certain modifications, is generally admitted to be correct. Conceiving that the appropriate and specific action of the lacteals is to nourish the body, and to support the system by the addition of new matter, that of the lymphatics is to mould and fashion the body, to admit of the growth and extension of the whole, while each individual part retains its proper form and position. When we consider in what manner an organized part increases in its dimensions, we immediately perceive that it is not by mere accretion, nor by simple distention; it is, on the contrary, by an addition to every individual portion, while they retain the same relation to each other and to the whole. If we take the case of a muscle, we find that each particular fibre must be increased in length, so that the distance may be augmented between the tendinous extremities, while probably the number of fibres that are contained in the membranous covering is also increased; the whole organ consequently becomes larger in every one of its individual parts, while they each retain their former proportions and connexions.*

We may apply the same train of reasoning to the bones, which offer a still more remarkable example of this change of form, inasmuch as the firmness of their texture must render it less easy to conceive of any alteration in their dimensions and in the disposition of their component parts. Here it is still more obvious than in the case of the muscle, that the change cannot be effected either by accretion or by distention, but that a completely new disposition of the integrant parts must have taken place. The only means, however, by which this can be accomplished is by the former particles of the body being gradually removed, and new ones deposited to supply their place; the process being so gradual, that, although the deposition of the new particle is not precisely in the same situation with the former, yet that of each particle is so nearly so as to cause no obstruction or interruption to the action of the organ. Now it is evident that this removal of the old matter can be effected by no process but by absorption, and we may therefore conclude that the lymphatics, either alone or in conjunction with the veins, are the agents destined to perform this office.

With respect to the actual nature of the contents of the lymphatics there appears to be some uncertainty. We have the analysis of the fluid taken from the vessels of a dog by M. Chevreul,* from which it would appear that the lymph contains nearly the same ingredients with the blood, but diluted with a much larger proportion of water. We must, however, suppose that the fluid contained in the lymphatics will vary very considerably in its composition, according to the part of the body from which it is taken, or the condition of the same part at different times; yet we are scarcely able to detect an actual state of things which altogether corresponds with what we might have been led to expect would have been the case.† It may indeed be presumed that in the ordinary condition of the system, the process by which the parts of the body are absorbed is so very gradual, that the change in the chemical constitution of the lymphatic fluid is as inconspicuous as the change in the organs from which it is absorbed, and that it is only in morbid cases, where there is some extraordinary quantity of matter to be removed, that we should expect to be able to detect it in the lymph. And this, to a certain extent, agrees with the fact; for when the absorbents are called into action to remove collections of pus, or when they become the vehicles of any poisonous or morbid body, the substance in question has been occasionally found in them.

The doctrine of the removal or absorption of all the parts of the body is rendered evident by a variety of cases, in which any particular organ or texture is broken down or removed, merely by cutting off the supply of fresh matter. It is upon this principle that we explain the

* See Winterbottom, de Vas. Absorb. in Smellie's Thes. Med. t. iv.; also Cruikshank, p. 108, 9. For the more recent views of physiologists on the subject the reader is referred to Adelon, art. "Absorption," Dict. des Scien. Méd. t. i.

* Magendie, Elem. t. ii. p. 171, 2.

† Magendie, Elem. t. ii. p. 196, 7, et alibi. Mascagni, however, states that the lymph varies according to the parts to which it is contiguous, ps. 1. §. 4.; see also Blumenbach, §. 438.

removal of a part by pressure. If a muscle, or even a solid bone be exposed to constant pressure, by which its nutritive arteries are obstructed, it will be gradually diminished in bulk, and at length completely abstracted. And this is frequently effected by the action of a body much softer than the substance which is removed, as, for instance, we observe a bone to be absorbed by the pulsation of a blood-vessel, or the growth of a fleshy tumour.*

But although we may venture to affirm that this moulding of the body, or rather of its individual parts, is effected by the lymphatics, either alone or in conjunction with the veins, there is considerable difficulty in forming a distinct conception of the mode in which they operate. The operation cannot, strictly speaking, be mechanical, nor have we any evidence of the existence of a chemical solvent, by which the parts may be reduced to a liquid state, so as to fit them for entering into the mouths of the vessels. We may conceive of the source of supply being cut off by pressure or in other ways, but still we are at a loss to account for the mode in which the solids are either dissolved or broken down, so as to adapt them to the process of absorption. There is, however, one principal or general fact in the animal economy, which will probably somewhat assist us in our inquiry, viz. that it appears to be essential to the well-being, or even to the existence of the corporeal frame, that all the materials of which it is composed should undergo a constant change. It appears that these materials, after a certain length of time, experience some alteration in their nature, by which they are rendered unfit for the further performance of their functions as constituents of the living body. They are therefore removed and are replaced by fresh matter, this interchange being brought about in the gradual manner which was described above. Now this process implies a constant decomposition of the parts of the body, and as this decomposition is effected particle by particle, it may not be unreasonable to conjecture, that each particle, when it ceases to form an integral part of an organ, is left in a state proper for being taken up by the absorbents. But independent of any hypothetical views of this description, we may assume it as a probable conclusion, that the configuration and moulding of the body is the specific and appropriate office of the lymphatics, while its nutrition is effected more immediately by the lacteals.

With respect to the lymphatic glands we have seen above that their structure is involved in considerable obscurity, and we may remark, that their use is at least equally obscure. Among other opinions that have been entertained on the subject, some physiologists have supposed that the glands are proper secreting organs, which are destined for the purpose of preparing a peculiar substance that is mixed with the chyle and the lymph, or that they merely serve the mechanical purpose of mixing together more completely the constituents of the fluid that is contained in the vessels, and thus produce some change in its nature or consistence.* There do not appear to be any arguments, either anatomical or physiological, by which this point can be decided; but we may remark, that while the number and mode of distribution of these glands in the mammalia would seem to point them out as performing some important office in the animal economy, their rarity in birds and fishes proves that they are not essential to the existence of most of the functions of animal life, nor have we any mode of explaining the cause why they should be more necessary to the mammalia than to the other classes, which in many of their functions so nearly resemble them.

It only remains for us to offer a few remarks on the connexion between the function of absorption, and the other vital actions of the system, especially with the two leading principles of contractility and sensibility. We have already had occasion to remark on the connexion of absorption with muscular contractility, and although it may be difficult, or even impossible, to demonstrate the muscular fibres, or to exhibit any apparatus of this description, by which the action of the vessels can be accounted for, still we have strong reason for supposing that the absorbents possess this power, and that it is the main cause by which their contents are propelled.

With respect to the relation which subsists between the nervous and the absorbent systems, we are induced to suppose, both from anatomical and from physiological considerations, that it is merely of an indirect nature. From the researches of the anatomists, we learn that there are few nerves sent to the absorbent vessels or glands, and that even these seem rather to pass by them, in order to be transmitted to some other organs, than to be ultimately destined for the use of the absorbent system. The action of the mouths of the lacteals, or the power by which they are enabled to take up the substances that are afterwards transmitted along them, is involved in much obscurity, as is likewise the case with the power which these vessels seem to possess of changing the nature of their contents. Both of these have been referred to the nervous influence, but this has been done in that loose and general way, which

* For the absorption of the solids, see Monro on the Brain, c. 5; also Blumenbach, §. 436; and Bell's Anat. vol. iv. p. 311, 2. Ribes, who is a zealous defender of the doctrine of venous absorption, remarks that the absorption of the bones must be effected by the veins, because they are not furnished with lymphatics; Mém. Soc. d'Emulation, t. viii. p. 621.

* On this subject we may refer to Haller, El. Phys. ii. 3. 25; Blumenbach, Inst. Phys. §. 425, 442; Richerand, Elem. p. 153; Mascagni, ps. i. sect. 5. p. 33; Magendie, Elem. t. ii. p. 166, 201; Chaussier et Adelon, ubi supra, p. 278. Rullier, art. "Inhalation," in Dict. Sc. Méd.; Meckel, Manuel, sect. 6. ch. i.; Adelon, art. "Lymphatique (Physiologie)," Dict. de Méd. t. xiii, also art. "Chylifères," ibid. t. v. p. 239; Desgenettes, Journ. Méd. t. xc. p. 322, et seq.

is too frequently met with in the reasoning of physiologists. We do not perceive, in either case, how it can be referred to this power, nor how it can be employed in any way to explain or elucidate the effects that are produced.*

It is admitted that the chyle is elaborated during its passage along the lacteals, and becomes more nearly assimilated, both in its physical and chemical properties, to the blood. Still, however, its complete sanguification does not take place until it leaves the lacteals, and it becomes a very interesting subject of inquiry, by what means this is effected; in what degree the function of respiration contributes to it, whether the abstraction of carbone and the introduction of oxygene, which is supposed to be effected by the passage of the blood through the lungs, is the immediate cause of the conversion of chyle into blood; whether it be brought about more gradually, by the removal of the various secretions and excretions, or whether there be any particular organ, which may more especially produce the change in question. These are all of them points of high interest, but as they are concerned in an indirect manner only with the subject of this article, and as they will be considered in the appropriate parts of this work, we shall not pursue the inquiry any further.

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(J. Bostock.)

* On this subject the reader is referred to Mascagni, p. 30; Hewson, pt. 3. p. 52; Cruikshank, p. 64; and Gordon's Anat. p. 77.

ACALEPHÆ (from ακαληφη, a nettle); syn. *urticæ marinæ*. Fr. *Acalèphes*; Germ. *Acalephen*; the name of a class of invertebrate animals. They are all inhabitants of the sea, and are such as are commonly known by the names of sea-jelly, sea-nettle, Portuguese man-of-war, &c. It is from the property, which many of these animals possess, of irritating the surface of our skin so as to produce nearly the same effect as that resulting from the sting of a common nettle, that the class derives its name.

Aristotle used the word ακαληφη to designate some of these animals; but it was by Cuvier that the class was formed, and the term acalephæ applied to it. As this class now stands in the last edition of the *Règne Animal*, (t. iii. p. 274,) it is formed chiefly by the animals constituting the Linnæan genus *Medusa* and *les acalèphes hydrostatiques* of Cuvier.

On many accounts the acalephæ are objects of extreme interest to the anatomist and physiologist. They have occupied the attention of the most learned naturalists of every age, from the time of Pliny until the present day; their numbers are, perhaps, greater than those of any other class of marine animals: they exist in all seas; and yet we remain very ignorant with regard to several points in their structure and history. The peculiar nature of their tissues, the singular arrangements of their organs, the anomalies in their functions, present as many objects of interesting inquiry to the physiologist, as the wonderful variety and striking elegance of their forms, and their splendid colouring present to the admiration of the naturalist. Peron,* in his animated description of the *Medusæ*, observes, "Among the animals of this family we find the most important functions of life performed in bodies which offer to the eye little more than a mass of jelly. They grow frequently to a large size, so as to measure several feet in diameter; and yet we cannot always determine what are their organs of nutrition. They move with rapidity, and continue their motions for a long time; and yet we cannot always satisfactorily demonstrate their muscular system. Their secretions are frequently very abundant, and yet the secreting organs remain to be discovered. They seem to be too weak to seize any vigorous animal, and yet fishes are sometimes their prey. Their delicate stomachs appear to be wholly incapable of acting upon such food, and yet it is digested within a very short time. Most of them shine at night with great brilliancy, and yet we know little or nothing of the nature of the agent which produces so remarkable an effect, or of the organs by which it is elaborated. And, lastly, many of them sting the hand which touches them; but how, or by what means, they do so still remains a mystery." It is, therefore, but a very imperfect account of the anatomy and physiology of this class that can be at present given.

The following are the names and characters of the groups into which the acalephæ have been divided by M. De Blainville,† whose arrangement is nearly the same as that adopted by Eschscholtz.‡

I. Physograda. Body regular, symmetrical, bilateral, fleshy, contractile, often very long, provided with an aeriferous sac. Branchiæ in the form of long cirri, very contractile.

1. Organ of natation simple and lamellated. *Gen.* Physalus. (*Physalia*, Lam.)

2. Locomotive organs complex and vesicular. *Gen.* Physsophora. Diphysa. Rhizophysa.

3. Locomotive organs in the form of smooth scales, disposed in transverse series. *Gen.* Stephanomia. Agalma. Protomedea. Rhodophysa.

II. Diphyda. Body bilateral and symmetrical, composed of a visceral mass of small size and of two swimming organs, hollow, contractile, somewhat cartilaginous, and placed one before the other, the anterior one being in more direct connexion with the central visceral mass, which it seems to surround; the other posterior, and very slightly adherent. Mouth at the extremity of a stomach more or less extensile. Anus unknown. A long filamentary organ, ovigerous, rises from the root of the central mass, and is prolonged more or less posteriorly.

Gen. Cucubalus. Cucullus. Cymba. Cuboides. Enneagona. Amphiroa. Calpe. Abyla. Diphyes. Ersaea. Eudoxia. Pyramis. Praia. Tetragona. Sulculeolaria. Galeolaria. Rosacea. Noctiluca. Doliolum.

III. Ciliograda. (*Ctenophoræ*, Esch.) Body gelatinous, free, varying in form, marked on the surface with narrow *ambulacra* formed by rows of vibratile *cilia*. Intestinal canal complete, with two orifices.*

Gen. Beroë. Eucharis. Mnenia. Calymma. Axiotoma. Callianira. Pandora. Medea. Alcynoë. Cestum. Cydippe. Idya.

IV. Pulmograda. (*Discophoræ*, Esch.) Body entirely gelatinous, circular, without any solid part internally, margin provided with cirri of various forms, or with foliaceous appendages pendent from the inferior surface.

1. Simple: without true tentacula, peduncles or arms.

Gen. Eudora. Ephyra. Phorcynia. Eulymene. Carybdea. Euryale.

2. Tentaculated: the circumference of the body, and sometimes the mouth, surrounded by tentacula.

Gen. Berenice. Equorea. Foveolia. Pegasia. Cunina. Ægina. Eurybdia. Thaumantias. Obelia. Linuche. Eirene.

3. Subproboscic: gastric cavity prolonged into a short peduncle, at the extremity of which is the mouth, surrounded by four brachial appendages.

Gen. Oceania. Aglaura. Melicerta. Saphenia. Tima.

4. Proboscic: the lower and central part of the body prolonged into a proboscis-like appendage, either simple or provided with arms.

Gen. Orythia. Geryonia. Dianœa. Favonia. Cytæis.

5. Brachigerous: lower surface furnished with more or less numerous appendages, brachial, ramified.

Gen. Ocyroë. Cassiopea. Medusa (Aurelia of Peron). Callirhoë. Melitea. Evagora. Cephea. Rhizostoma. Chrysaora. Cyanea. Pelagia. Sthenonia.

V. Cirrigrada. (*Velellidæ*, Esch.)

* Peron. Ann. du Mus. xiv. 220.

† Dict. des Sc. Nat. "Zoophytes." 1830.

‡ System der Acalephen. Berlin, 1829. The most complete treatise on the anatomy and history of the acalepha hitherto published. Its learned author enjoyed excellent opportunities of studying these animals in the course of the two voyages round the world undertaken by Kotzebue, of whose expeditions he was naturalist.

* M. De Blainville regards the animals included in this and the two preceding sections as being more allied in structure to the Mollusca, (his *Malacozoaires*,) than to the Radiata, with which they are arranged by most zoologists. Accordingly he separates them from the two succeeding sections, which are truly radiate animals, and of which he forms a class in his great division *Actinozoaires*, under the name of *Arachnoderma*.

Body oval or circular, gelatinous, supported by an internal, solid, subcartilaginous body, and provided with very extensile tentacule-like cirri pendent from the whole of the lower surface.

Gen. Velella. Porpita. Rataria.*

Of the genera above enumerated, Eschscholtz has described about two hundred species. Messrs. Quoy and Gaimard have made us acquainted with several others; but of all these a comparatively small number only have been described in detail: so that, although in the account which we are now to give of the anatomy and physiology of the acalephæ, we shall, for the sake of brevity, make use of the sectional designations, it must be understood that the descriptions apply only to a few species, and that, with regard to the others grouped along with these, we can only say it is *probable* that they are similarly constructed.

I. *Locomotion.* The principal organ of locomotion in the physograda is the air-filled vesicle or bladder, which exists, of various sizes, in all the species. In *physalus*, (*Fig.* 6.) it is a large organ, forming a great portion of the general mass of the animal. It is placed superiorly, and, for the most part, rises above the surface of the water. It has an elongated form; the longest diameter being the horizontal. It is somewhat pointed at one end, at the other truncated; and at either there is a small opening, the place of which is marked by a superficial dimple, surrounded by delicate muscular fibres, acting as sphincters. When

(*Fig.* 6.)

Physalus Utriculus, (Esch.)

the bladder is squeezed by the hand, so as to force the contained air towards one of these openings, the air makes its escape through it; but whenever the pressure is taken off, the opening again closes. M. De Blainville states that he has satisfied himself that this air-bladder is really a dilatation of the intestinal canal; and that he regards the two openings mentioned above as the mouth and the anus. We are ignorant of the data upon which M. De Blainville grounds his conclusion. It does not appear that any observer has found alimentary matter lodged within the air-sac. But whether or not it be an organ of digestion, it is certainly an organ of locomotion, although only a passive one; for it is by its contained air that the animal floats on the surface of the water, so as to expose a large superficies of its crest and bladder to the wind, by which it is driven to and fro frequently with great velocity. The walls of this sac are muscular, so that by their contraction its cavity can be considerably diminished. And thus, partly by the escape of air forced out through the openings, and partly by the compression of what remains, the specific gravity is so much altered as to admit of the

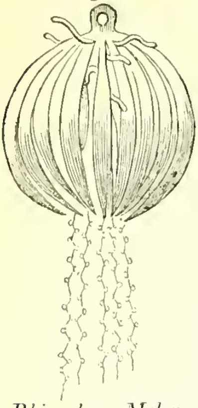
* The following neat but artificial arrangement of *acalephæ* forms the subject of a communication lately made to the Zoological Society by M. Lesson, foreign member of that body: we are indebted for it to our friend Mr. Owen.

- I. Without a central solid axis.
  - A. Body simple, entire.
    - 1. Symmetrical, terminated at each pole by an opening . . . . 1 *Beroidæ.*
    - 2. Non-symmetrical, the upper pole disciform or umbelliform, imperforate . . . . 2 *Medusæ.*
  - B. Body multiple or aggregated.
    - *a.* Homogeneous.
      - 3. Composed of two pieces adhering together, and capable of separation . 3 *Diphydes.*
      - 4. Composed of numerous pieces aggregated together . . . . . . 4 *Polytoma.*
    - *b.* Heterogeneous.
      - 5. Animal furnished with appendages of different kinds.
        - * Vesicle small, regular, placed at the summit of a kind of stalk furnished with lateral ampullæ, and terminal suckers . . . . . 5 *Physsophoræ.*
        - ** Vesicle large, irregular, without stalk or ampullæ, but having terminal suckers and cirriferous processes . . 6 *Physaliæ.*
- II. With a central cartilaginous axis.
  - 6. Body simple, with suckers and lateral *tentacula.*
    - *a.* Body irregularly oblong, with a vertical lamina on its upper surface . 7 *Velellæ.*
    - *b.* Body discoid, flat above. 8 *Porpitæ.*

R. B. T.

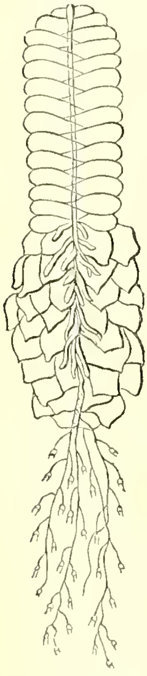
animal's sinking into the deep when danger threatens. In the other physograda, the air-vesicle is so small in proportion to the general mass of the animal that it is not sufficient to raise it above the surface of the water. It is generally an ovate sac, with an opening at its upper end, closed by a sphincter muscle. It is probable that its walls are muscular, and that by pressing out a portion of the contained air, and by secreting more, alternately the animal can sink and rise at pleasure. The nature of the air contained in these vesicles has not yet been ascertained. In *rhizophysa* (*Fig.* 7.) there are, pendent from one part of the body, certain peculiar organs, arranged very regularly in pairs, of a muscular structure, hollow, and furnished each with a round orifice. They differ from the tentacula in structure, and are, probably, organs of natation. Similar tubes, but only two in number, exist in *diphysa*; and, anterior to them, in the same animal, there is a two-lobed organ, the use of which is doubtful. In *agalma*, (*fig.* 8.) and some of the genera allied to it, there are certain cartilaginous plates disposed in an imbricated manner along the sides of the body. These, Eschscholtz regards as locomotive organs. The muscles by which they are set in motion must be extremely delicate, as a slight touch is sufficient to separate the plates from one another.

Fig. 7.



Rhizophysa Melon.

Fig. 8.

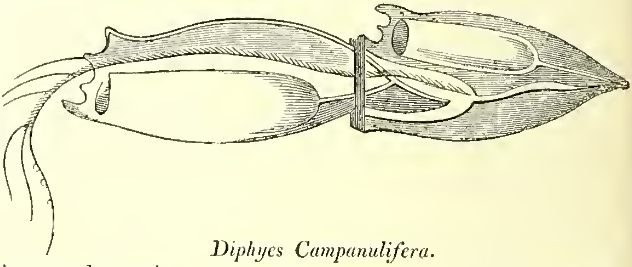


Agalma okenii.

The chief bulk of the singularly formed diphyda is made up of the swimming organs, which are two subcartilaginous bodies, polygonal, generally pointed anteriorly, truncated posteriorly, placed one behind the other, and one a little within the other; the posterior portion being lodged in a little excavation which exists in the anterior. These two parts differ somewhat from one another in form, but both are hollow, and have large openings. Their attachment is so slight as to admit of their being separated by agitation of the water. It is at the bottom of the anterior cavity that the essential parts of the animal are placed. Locomotion is effected by means of the impulse of a current which is kept up by the successive contractions and dilatations of the organs above described. The contractions of the two bodies are not synchronous; but they succeed one another within a short time, so that a steady progression is maintained; and in some species it is very rapid.

In the ciliograda, the locomotive organs are large cilia, disposed in longitudinal bands on the surface of the body. These bands are generally eight in number; but in some species, (e. g. *axiotoma Gaedii*, Esch,) there are only four. The arches supporting the cilia are of firmer texture, and are less transparent than the rest of the body. In many species they extend from one end of the body to the other; in some only along a part of the circumference. The structure of the cilia themselves has lately

Fig. 9.



Diphyes Campanulifera.

been examined by Dr. Grant,* with his usual care, in the *Beroë pileus*;† and he has found that they are fin-like processes, and that each is composed of several short, transparent, somewhat curved filaments, placed parallel to each other in a single row, and connected together by the skin of the animal, like the rays supporting the fin of a fish. The rays in the middle of the cilium are a little longer than those at the sides. All the rays appear as transparent tubes under high magnifying powers. They are so curved that their extremities are directed backwards towards the closed extremity of the animal. There are about forty cilia attached to each arch in this species, which is nearly an inch in length. The cilia are so large as to be visible to the naked eye. Most of the ciliograda have their cilia quite exposed; but *Pandora* is provided with moveable folds of the skin along the cilia-bearing arches, which can be brought over the cilia, in whole or in part, at the animal's pleasure, so as to cover them more or less completely. These cilia are moved nearly in the same manner as the pectoral fins of fishes. But their motion is so rapid, when the animal is vigorous, that the eye cannot follow it. The existence of motion is pointed out, however, by lines of beautiful iridiscent colours playing along the arches, and

* Trans. Zool. Soc. of London, i. 10.

† Pleurobrachia pileus. Fleming. Brit. Anim. 504. Cydippe p. Esch.

by the currents which are generated in the circumambient fluid. The animal has the power of arresting completely the motion of one, two, or more rows of cilia, while the others are moving. When all are set in motion together, the animal moves onwards with the inferior or oral surface (inferior in a state of rest) directed forwards. When the motion of some is arrested, the whole body acquires a rotatory motion, and advances in a curvilinear path. The animal has also the power of changing the direction of the currents caused by its cilia, so that it can ascend or descend in the water at pleasure. It can also increase and diminish at will the velocity of the motions of the cilia. Those animals which have the largest cilia, (e. g. *Medea*,) swim with the greatest rapidity. The cilia continue to move for some time after having been separated from the body, in connexion with part of their arches. Immediately beneath the arches there are vessels conveying a fluid, which is in motion during the vibrations of the cilia. Whether these vessels are destined only for the conveyance of the circulating fluid to the cilia, (which in all probability act as organs of respiration as well as of locomotion,) or carry a stimulus fitted to excite their vibrations, is not yet determined. Eschscholtz compares these vessels to those which Tiedemann has described as connected with the feet in the echinodermata. And Dr. Grant is of opinion, with MM. Audouin and Milne Edwards, that it is not improbable that the motions of the cilia are somehow dependent on the movements of the fluids contained in the above-mentioned vessels, seeing that in the *actiniæ* the tentacula are projected by water being forced from below into them. In the other classes of the acalephæ also the same kind of structure prevails. Such of the pulmograda as have cilia around their margins have also circular vessels running along their bases; and almost all projectile and extensile tentacules and filaments are provided with sacs and canals, containing fluids, at their roots.

In addition to their cilia, several of the ciliograde acalephæ have other organs of locomotion in the form of long filamentary arms or tentacules, with which they can poise themselves in the water without moving their cilia. In *Cydippe** these are two in number. They are lodged in two tubes placed alongside of the stomach, from which they issue near the mouth. They can be extended to four times the length of the animal. They terminate in very fine points, and along their whole course present minute filaments placed at equal distances, which are coiled up spirally, close to the tentacules, when these are about to be withdrawn into their sheaths. The tentacules are also coiled up in a spiral form when completely contracted. They are sometimes suddenly sent forth from their tubes to their full length by one impulse, and then their lateral filaments are gradually uncoiled; a process this of no less interest on account of the gracefulness of the motion than on account of the peculiar mechanism which it indicates.

* Grant. Trans. Zool. Soc. i. 10.

The principal organ of motion in the pulmograda is the large campanulate, or mushroom-shaped, disc, of gelatinous consistence, which constitutes the great mass of the animal. In this, for the most part, no muscular fibres can be seen, and yet the animals move about with some quickness. They have the power of contracting and dilating their discs at pleasure, in whole or in part. By alternately contracting and dilating their inferior surface, they strike the water in such a manner and with such force as to raise themselves; when they discontinue this motion, they again sink, being of greater specific gravity than the sea-water. They move onwards horizontally, by acting only with one side of the margin of their disc. Lamarck was of opinion that these isochronous movements of the disc, by means of which the pulmograda seem to swim, were fitted merely to facilitate the internal vital processes, and not to move the animals through the water; and he regarded them as dependent entirely on the influence of imponderable agents existing in the circumambient fluid, and alternately entering into, and flowing from, the general mass of the animal. He compared the motions with those of the fluid in Franklin's thermoscope, when held in the hand.* In the course of the ordinary progression of the large *Medusa aurita* of our seas, the contractions of the disc take place from twelve to fifteen times in a minute. The convex surface of the disc always advances foremost.

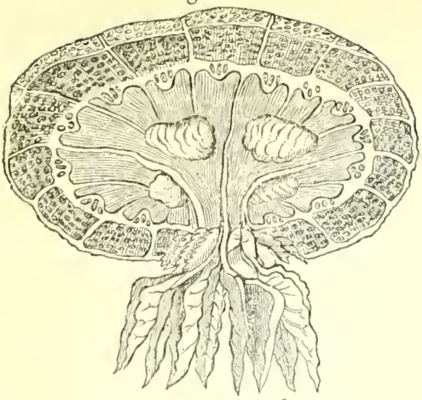
No fibrous structure has hitherto been discovered in the general mass of the disc. Internally, it is cellular, uniform, and very soft. The quantity of solid matter in the disc, and, indeed, in the whole body, is very small. Some *medusæ*, which, when recently taken out of the water, weighed fifty ounces, on being dried, left remains weighing scarcely more than five or six grains. "It is therefore evident, that the sea-water, penetrating the organic texture, constitutes the greater part of the volume of these animals."† But in some species there exists a fine muscular membrane, stretched over a certain extent of the lower surface just within its outer margin. Under a lens, this has the appearance of being composed of numerous fleshy fibres, forming little bundles, arranged in a radiate manner as regards the axis of the animal, and closely adherent to the gelatinous tissue of the disc. When portions of the disc are cut off from living *medusæ*, without any part of this muscular membrane being attached to them, they remain motionless; but when their connexion with the membrane is preserved, even small portions continue their motions of contraction and dilatation for a considerable time.

The tentacula of the pulmograda (which are always pendent from the inferior surface) may be regarded as supplementary organs of locomotion, although they are, in all probability, subservient chiefly to the nutritive function. They are all simple, not branched, generally

* Anim. sans Vert. ii. 454.

† Spallanzani, Travels in the Two Sicilies, iv 218.

Fig. 10.

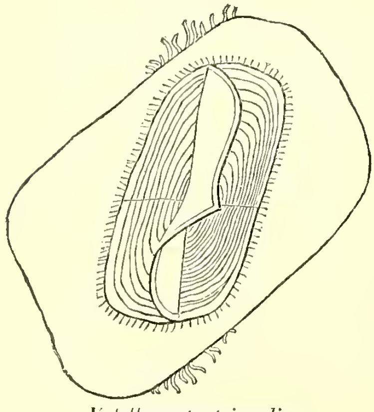


Rhizostoma cærulea.

hollow; and, when connected with the appendages of the digestive cavities, or when they have a vesicle at their base, very extensile. Several genera have suckers at the extremities, and along the sides, of their tentacula, by means of which the passing prey is seized. The tentacula which are extensile seem to be projected by the forcing of water into their internal cavity, by the contractions of the vesicles at their base. The extent to which the filamentary organ is thus lengthened, in some species, is very extraordinary.* It seems to be shortened again by means of the contractions of circular muscles, which force back the water into the vesicle, and of longitudinal muscles which draw it in. Peron thought that some of the pulmograda were furnished with internal air-bladders; but Eschscholtz, on directing his attention to this point, satisfied himself that what Peron had taken for air-bladders were merely appendages of the gastric cavities, into which air had accidentally been introduced during the removal of the animals from their native element.

In the cirrigrada, locomotion is effected

Fig. 11.

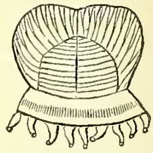


Velella septentrionalis.

* In the tentacula of some of the physograda, also, a similar extensibility exists. The lower surface of *physalus*, for instance, which itself seldom exceeds six inches in length, is provided with tentacula sixteen and even eighteen feet long.

partly by the movements of the tentacules which hang down from the inferior surface; but chiefly, perhaps, by the action of the wind on the raised crest, with which most of these animals are provided. Immediately around the mouth are placed numerous small tubular suckers, similar to the feet of many echinodermata. Exterior to these there are longer tentacula, for the most part in a single row, and simple; sometimes branched. Neither of these two kinds of organs is very extensile. The disc from which the tentacules hang, and the crest, are supported internally by a calcareous plate, which is the only organ of the kind in the whole class of acalephæ. It somewhat resembles in structure the calcareous axis of *retepora*, being cellular and porous. Its numerous cells are filled with air, which renders the whole animal so buoyant that it floats on the surface of the water, and is wafted along by the winds. In *velella* (*Fig.* 11.) there are two plates, one placed horizontally, the other perpendicularly upon the upper surface of the former. They are marked with lines of growth, enlarging from within outwards, like the extravascular shells of the mollusca. The perpendicular plate in velella supports the crest, which stands upright, and exposes a large surface to the wind. *Rataria* (*Fig.* 12.) has its crest provided with strong muscular bands running perpendicularly. It lies on the surface of the water, with the crest stretched out, so that its whole side touches the water. When it is alarmed, the crest is suddenly contracted, and the centre of gravity is so altered in consequence, that the position of the body is almost reversed. When the crest is again raised, the body immediately resumes its former position.

Fig. 12.



Rataria cordata.

Porpita has a simple plate supporting its disc, without any crest, and long tentacula, which are so delicate as scarcely to bear the slightest touch when the animal is taken out of the water. When the position of the animal is altered by the hand, so as to make the surface covered with suckers the upper one, all the tentacula of one half of the body turn round to the dorsal surface, and all those of the other half stretch over their own surface, and thus the animal very soon regains its old position.

II. *Motility and Sensation.* — Almost all observers have failed to discover anything resembling a nervous system in the Acalephæ. Even Eschscholtz,* who devoted so much attention to their anatomy, could not see nerves in the largest that he examined. But in *Cydippe*, according to Dr. Grant,† there is a structure which can be regarded only as belonging to the nervous system. It consists of a double transverse filament of a milky white colour, running round the body, near its surface, at a short distance above the mouth. The two cords of which this filament is composed unite in the middle of each of the spaces between

* System, p. 19.

† Trans. Zool. Soc. of Lond. i. 10.

the ciliated arches to form eight ganglia, from each of which two nerves go to the adjoining bands, and one, larger than the others, runs upwards in the middle of the transparent space between the bands, and can be traced to beyond the middle of the body. In the course of these last-mentioned nerves, two or three smaller ganglia are visible, from which filaments pass inwards to the viscera. Dr. Grant likens these nerves and filaments to the abdominal nerves of *pectinaria* and other transparent animals.

The circular fibres forming the sphincters of the orifices of the air-bladder in *physalus* have been mistaken for nerves.*

There is no evidence that the acalephæ possess any other sense than that of touch. But, although they cannot be said to have the sense of sight, they are evidently affected by light. At least some of the smaller tribes shun a bright light, and sink into the deep to escape from it.

In most of the tribes of acalephæ, the sense of touch seems to have its seat chiefly in the tentacula and cirri, with which almost all are provided. The degree of sensitiveness with which these are endowed varies much. In some, the slightest touch, even agitation of the water, is sufficient to excite them to contraction. These organs of touch, as has been already mentioned, are subservient chiefly to the nutritive functions. Other parts of the bodies of most acalephæ also manifest, by their contractions, a certain degree of sensitiveness. Several of the ciliograda alter the shape of their general mass when touched. In physalus the crest appears to be more sensitive than any other part. Many species, particularly of the pulmograda, give no signs of their feeling even the deepest and most extensive wounds of their discs. But it was observed by Spallanzani, that, by friction, and by punctures of the muscular membrane of the disc, the movements of contraction and dilatation could be excited in medusæ, which, having been kept in a dry place during twenty-four hours, had discontinued their ordinary motions, and had lost nearly two-thirds of their bulk by the running out of their contained fluids.†

* Isis. Nov. 1819.

† Professor Ehrenberg has very recently attempted to shew that *medusa aurita* is possessed of eyes, in the form of minute red points, which are seen on the surface of the eight brown-coloured masses set round the circumference of the disc. These masses, according to his observations, consist each of a yellowish, oval, or cylindrical little body, which is attached to a small and delicate pedicle. This short pedicle arises from a vesicle, in which there is placed a glandular body, unattached, presenting a yellow colour when viewed with transmitted light, a white colour under reflected light. It is upon the dorsal aspect of the yellow head, which surmounts the pedicle, that the well defined red point is seen, which Ehrenberg considers as an eye. He compares the eyes of *medusa* to those of some *rotifera* and *entomostraca*. The glandular body situated at the base of the pedicle, he regards as an optic ganglion, which, he seems to have satisfied himself, is connected with two filaments that decussate one another at about the middle of their course. These he describes as forming part of a nervous circle placed, throughout the greater part of its course, immediately along the bases of the row of tentacules that surround the disc, so as to form, as it were, the outer wall of the circular vessel, or appendage of the intestinal cavity, which runs round the margin of the disc. The same observer describes another nervous circle, composed of four ganglion-like masses, disposed around the mouth, each being in connexion with a corresponding group of tentacules. (Ehrenberg, in Müller's Archiv für Anat. Physiol., &c. 1834. p. 562.)

III. *Digestion.*—The structure and action of the organs concerned in the function of digestion in the acalephæ are still involved in much obscurity. Even in the large and frequently examined physalus, it is difficult to ascertain the functions of the various parts in a satisfactory manner; and, accordingly, there exists so much difference of opinion amongst anatomists with regard to them, that some will not even admit that it has a mouth, while others assign to it both a mouth and an anus, as well as cœcal prolongations of the stomach. Eschscholtz concluded, from his numerous observations on the living animals, that, in all the physograda, the digestive organs consist merely of absorbing tubes or suckers, all of which are simple, and pendent from the inferior surface. He seemed to think that the action of these filamentary organs was analogous to that of the roots of plants;—that they were endowed with an endosmosic power, which enabled them to imbibe nutritious matter from the water. However this may be with regard to the simple filaments, or cirri, it appears probable that the *suckers* are provided with orifices at their extremities, through which proper alimentary matter passes into the interior; for several observers agree in stating, that both the physograda, and the diphyda apply their suckers to the bodies of other animals, and remain adherent to them for some time, during which they seem to take up some nourishing matter. *Eudoxia* has only one sucker. Messrs. Quoy and Gaimard have described in detail the singular filamentary organ which bears these suckers in *diphyes*. Generally it is seen, at first, only as a shapeless opaque mass, of a reddish colour, lying contracted within the swimming cavity. But, gradually, it is extended, and then there are perceptible, along the whole of one side of a fine transparent tube, numerous suckers, of a lengthened form; each is covered by a very delicate bell-shaped case, and has its base surrounded by groups of minute vesicles, which are, probably, the ovaries. From the base there arises also a little tentacule or filament, susceptible of very great elongation, and which sends off many secondary filaments.*

The digestive organs of the ciliograda are less dubious. In these we find uniformly a straight alimentary canal with two orifices, the mouth inferior, the anus superior, in the ordinary position of the animal. In some species there are lips formed by short and broad folds of the integument, four in number, and very sensitive. In cydippe, Dr. Grant found these lips capable of rapid extension and retraction.

* Ann. des Sc. Nat. x. 8.

The mouth is large, the œsophagus straight and wide; the stomach is, for the most part, of an ovate form, the intestine passes in a straight line, and with a uniform diameter, to its extremity. The anus has a prominent circular margin in cydippe. No absorbent vessels can be seen arising from the gastric cavity. In many species, the alimentary canal is so large as to occupy the greater part of the interior of the body. When there is no food within it, it remains open at both extremities, and, as the animal swims generally with its mouth foremost, there is a current of water continually passing through it. Eschscholtz observed, that when suitable aliment was carried by this current against the walls of the stomach, the orifices were immediately contracted, and the digestive process begun. Minute crustacea, salpæ, &c., have been found in the stomachs of ciliograda. The diligent observer just mentioned seemed to regard the canal leading from the stomach to the dorsal surface, (which we have called the intestine,) as forming no part of the digestive organs. He termed it " the water-canal," and considered it as connected merely with the peculiar mode of locomotion, inasmuch as he observed it so patent while the animal was swimming and not digesting as to admit of a free passage for the water; which, otherwise, in entering the open mouth, would have much impeded progressive motion.

It was generally believed, until within a very recent period, that some of the pulmograda were destitute of stomachs. Hence the term of *agastric medusæ* which was applied to them by Peron. The researches of Dr. Milne Edwards, however, have rendered it probable that this supposition was erroneous, and founded on inaccurate observations. We have now reason to believe that all the pulmograda have gastric cavities; but all have not true mouths. There are some in which the only communication between the stomach and the outer surface is through numerous ramified canals in the pendent arms, which open externally by extremely minute orifices, barely sufficient, even in large species, to admit the smaller entomostraca. Such a structure exists in *rhizostoma*. By injecting milk into its gastric cavity, the canals in its arms, and their oscules can be rendered visible; and it is then discovered that from the minute oscules, which are situated in indentations along the margins of the arms, small vessels proceed inwards, and, uniting in twos and threes together, open into one large canal which runs through the middle of each arm. These arms are large, fleshy, foliated organs, eight in number; each of which has a triangular shape. The eight canals above mentioned unite two and two, so as to form four great trunks, which open into a large central cavity,—the only one in the body. This cavity is situated at the base of the central process pendent from the lower surface of the disc. The base, in rising upwards, enlarges into four fleshy columns, which lose themselves in the disc. It is between these four fleshy columns that the cavity of the stomach is placed. The intervals between the columns would form so many openings into this cavity were they not closed by a fine and plaited membrane, which bulges outwards when the stomach is filled. From the circumference of the stomach, at equal distances, sixteen vessels arise, and run directly towards the margin of the disc. These vessels may be regarded as arteries, and will be hereafter described along with other structures more nearly resembling the parts of a circulating system. But Cuvier* was disposed to consider them as cœca; although he admitted that he could discover no other vessels fitted to discharge the functions of arteries. He remarked that if we regard them as arteries, we must look upon the little vessels which lead from the appendages or arms to the central cavity, as veins, or as lymphatics; and then we might say that the sea is as a stomach to the *rhizostoma*, in the same way as the earth acts as a stomach for plants. But, at all events, Cuvier was convinced by his dissections that alimentary matter enters the body through the marginal oscules of the arms, and that it is accumulated in the internal cavity before passing into the radiating vessels. By experiments on the living animal, Dr. Milne Edwards has recently proved† that the circumambient fluid and its contents of minute size do really enter the body of the *rhizostoma* through the margins of the arms. He placed a living rhizostoma in sea-water, artificially coloured red. The animal did not appear to suffer from the presence of the colouring matter. Within a very short time, the puckered membrane which borders the arms was distinctly tinged red, and, gradually, the colour ascended, until the whole body assumed the same tint. Dr. Edwards does not state, however, whether he traced the progress of the coloured fluid through the brachial canals and the vascular system. On placing the same individual again in pure sea-water, the colouring matter which had been absorbed disappeared gradually, and it seemed to Dr. E. that it was thrown out chiefly from the brachial fringes, but partly also from the margin of the disc, and from the capillary orifices situated at the extremities of the arms. Dr. Edwards satisfied himself that it is impossible for animals larger than small animalcules to enter the central cavity of the rhizostoma. But most of the pulmograda have large central mouths, either simple and sessile, or placed at the extremity of a projection from the lower surface of the disc. In some, the mouth is more or less patent, but capable of being closed by the approximation of the base of the arms. In others it is surrounded by a ring of considerable density, in which muscular fibres can be distinctly seen. In *medusa aurita*, there are, just within the cavity of the mouth, four openings, which lead, by as many short but wide canals, into four spherical sacs of considerable size. These are completely separated from one another by membranous partitions. That they are stomachs is proved by the circum-

* Journ. de Phys. xlix. 438

† Ann. des Sc. Nat. xxviii. 249.

stance of fishes being found in them.* From each sac, four vessels arise, which run outwards to the circumference of the animal. Other species (e. g. *medusa capillata*) have the four gastric sacs in free communication with one another; and, frequently, (e. g. in *pelagia*, *chrysaora*, and *ægina*,) in connexion with these, there are four other sacs, lined with a more dense membrane than the former. These gastric appendages have the form of simple canals in *equorea* and *tima*; and of branched vessels in *medusa* and *sthenonia*.

They were chiefly such pulmograda as have their disc bell-shaped that were formerly supposed to be *agastric*. It was imagined that alimentary matter being received within the campanulate depression, its orifice was contracted, and nourishment taken up by imbibition through the walls of the disc. But an attentive examination of *Carybdea marsupialis*, (Peron,) one of the animals which was believed to be agastric, has satisfied Dr. Milne Edwards that a mouth and an internal cavity connected with it do really exist. The great transparency of this animal renders the discovery of its internal structure a matter of considerable difficulty, excepting when coloured injections are used. Dr. Edwards found within the funnel-shaped cavity of Carybdea, and, as it were, pendent from its roof, a projection of very delicate tissues, evidently forming tentacula surrounding a central mouth, and a stomach, from which proceed four long canals leading to the tapering filaments which hang down from the margin of the body of the animal. These canals, Dr. Edwards believes to be analogous to the radiating vessels of rhizostoma. There exists just at the commencement of each canal, and opening into it, a group of minute cylindrical sacs, which may be regarded as biliary organs.† But in most of the pulmograda these organs are situated on the margin of the disc. Generally, they present the appearance of glands, being distinctly granular in their structure. They are opaque, have a lengthened form, and are lodged in little depressions, and surrounded by cup-shaped folds of the external integument. They are connected with the gastric appendages by small tubes.‡

In *Aurelia phosphorea*, (Lam.) (*Pelagia*, Esch.) which formed the principal subject of Spallanzani's observations on the acalephæ, there are four groups of membranous tubes, convoluted, and resembling in structure the intestines of vertebrate animals. Although he did not trace their connexions, Spallanzani appears to have regarded them as truly parts of the alimentary canal. He observed that they exhibit a peristaltic motion, both in the water and in air, which can be increased by the application of stimuli.§

The food of the pulmograda consists of various marine animals—small fishes, mollusks, crabs, and worms. Even large fishes are sometimes found entangled amongst the arms and tentacules. They are probably killed by the peculiar excretion which covers the surface of these organs, and which produces a stinging effect on man. The long filamentary appendages which hang from the margins of the disc in Carybdea and others, are covered with a glutinous matter to which passing objects adhere; the animal has the power of stretching them out and withdrawing them at pleasure, and of so folding them inwards as to carry to the mouth whatever may be attached to their sides. It would appear that some species are endowed with the power of discriminating the food most suitable to their own nature. Gaede remarks that he has never found fishes in the stomach of *medusa capillata*, but often worms; while in that of *medusa aurita* there are frequently fishes, rarely worms. In none of the pulmograda have either masticatory or salivary organs been discovered.

The cirrigrada have, in the middle of their lower surface, a large flask-shaped stomach, the mouth of which is formed like a sucker. There appears to be a communication between this organ and the numerous tentacula which surround the mouth, through minute canals. The food consists of small animals, such as entomostracous crustacea; the undigested remains of which are again ejected through the mouth.

IV. *Circulation.*—No distinct circulating system has hitherto been discovered in the acalephæ. But perhaps the peculiar apparatus of radiating vessels connected with the gastric cavities in the pulmograda, and the aquiferous canals of the ciliograda, which seem to perform nearly the same functions as the vascular system of higher animals, may be conveniently and properly considered under this head.

In the physograda, Eschscholtz saw what he considered as the rudiments of a circulation; namely, distinct vessels arising from the roots of the tentacula, and ramifying on the internal surface of the air-bladders; but it does not appear that he traced these further, or that he saw the movements of a fluid within them.

The vessels in the ciliograda, within which a fluid is seen to move, are situated chiefly beneath the cilia-bearing arches. This fluid is supposed by most modern anatomists to be merely water; but by some it is regarded as a peculiar fluid, the product of the animal's digestive powers. If it be water only, the canals in which it moves must be considered as being analogous to those of the aquiferous system of other classes of invertebrate animals, which has been so fully illustrated by the researches of Delle Chiaje,* and which is presumed to be subservient to the respiratory function. The vessels in question arise in *Beröe* from a vascular circle which surrounds the intestine near the anus. They are eight in number, and one runs beneath each cilia-bearing arch, from one extremity of the body to

* Gaede, Beyträge zur Anat. ünd Phys. der Medusen.

† Ann. des Sciences Nat. xxviii. 251.

‡ Eschscholtz, op. cit.

§ Travels, iv. 228.

* Mem. sur la Storia e notomia degli animali senza Vertebre, 4to. Napoli, 1823-25.

the other. They then terminate in another annular vessel, which surrounds the mouth. In their course they give off numerous branches. From the oral circle of vascular structure arise two large vessels, which run along the walls of the gastric cavity, and appear to unite with the other circle at the anal extremity. These last Eschscholtz regarded as veins, and the eight external vessels as arteries. He supposed that the veins, passing along the walls of the stomach, absorbed the nutriment, and then carried the circulating fluid to the cilia for aëration. In the course of his observations on the *Beröe ovatus*, Dr. Fleming* distinctly saw a fluid moving " backwards and forwards" in the external vessels; and he states that " while the animal was active, there were numerous small spaces in the different vessels where the contained fluid circulated in eddies." Dr. Fleming failed to detect any structure in the vessels which could produce these partial motions. In *cestum naiadis*, Eschscholtz thought that he saw the system of vessels more distinctly than in any other of the acalephæ. He thus described it: " From the base of each of the two tentacules, a vessel takes its rise, and goes towards the bottom of the stomach. Here the two vessels unite, and form a little vascular circle around the water-canal (intestine). From the upper margin of this circle, four straight vessels arise, which go towards the two rows of cilia-bearing organs placed on the dorsal surface. Under these they run, two in one direction, and two in the other. At either extremity of the body, these unite with certain vessels running superficially along the sides, and which complete the circulation by entering the first set of vessels just before they begin to run beneath the ciliated organs. All these vessels are simple canals, of the same diameter throughout, without any visible branches. They contain a colourless watery fluid, in which minute yellowish globules are seen to move. In the vessels which arise from the bases of the tentacules, the globules mount upwards; they assume a rotatory motion in the vascular circle; and, in the four dorsal vessels, they seem to move, some in one direction, others in the other. It is probable that what appears to the eye as one vessel, is, in reality, composed of two vessels, running parallel and close together."†

Seeing that the radiating vessels which arise from the gastric cavities of the pulmograda seem to carry out the nourishing material to all parts of the body, and that they are, in some species at least, connected with other vessels which form a complete circle, we are disposed to class them under this head along with the vascular structures already described. The exact analogies of their functions, however, have not yet, we conceive, been distinctly made out.

From the stomach of rhizostoma, formerly described, sixteen vessels arise, and pursue a straight course outwards to the margin of the disc, near which they all enter, at equal distances, a circular vessel, which passes completely round the circumference of the animal. Four of the radiating vessels correspond with the four fleshy pillars of the process supporting the arms, and there exists on the internal surface of each of these pillars, a groove, which establishes a direct communication between the corresponding vessel, and one of the large vessels of the central process. The other twelve are distributed by threes in the intervals between the first four, and arise from those parts of the stomach which are closed by the plaited membranes. The space intervening between the circular vessel and the margin of the disc is occupied by an innumerable multitude of little vessels which form a net-work like the finest lace.* In medusa aurita, there are also sixteen radiating vessels, four of which arise from each of the four sacs, into which the gastric cavity in this species is divided. Two of the four vessels in each group are simple, the other two are several times bifurcated; both the simple main trunks and all the branches so formed, enter a circular vessel surrounding the disc, which seems to be connected also with the tubular cavities of the numerous cilia which surround the margin like a fringe, and which are capable of elongation and contraction.† Carus remarks with regard to the circular vessel, that " it may be considered as an extremely simple rudiment of the great circulation of superior animals, in case we view the radiating as chyliferous vessels."‡

V. *Respiration.*—It is probable that the air-bladders of the physograda, the swimming organs of the diphyda, and the cilia of the ciliograda are all subservient, in a greater or less degree, to the respiratory function, as well as to locomotion. The vessels in the last mentioned class, which have been described above as appertaining to the circulating system, are regarded by some as respiratory organs; and by Lamarck were compared to the tracheæ of insects. They have been called *aquiferous tracheæ*. Those who consider them in this light believe that they are open at two points, so as to admit the circumambient fluid to pass freely through them. The most recent and accurate observations, however, leave it doubtful whether this really takes place in the ciliograde acalephæ.

With regard to the pulmograda, several parts and organs have been pointed out by different observers as being, in all probability, the seats of the respiratory function. Cuvier thought that the delicate plaited membranes which exist between the fleshy pillars of the central process in *rhizostoma*, and which form in part the walls of the stomach, might be regarded as the organs of respirarion. Eisenhardt supposed that he saw them in certain tentaculated processes attached to the membranous partitions which divide the gastric sacs of some species from one another; while Gaede looked upon the four small sacs which overlie the

* Mem. Wern. Soc. iii. 401.
† Op. cit. p. 14.

* Cuvier, Journ. de Phys. xlix. 438.
† Gaede, Anat. der Medusen.
‡ Carus, Comp. Anat. (by Gore,) ii. 266.

gastric cavities in *medusa aurita* as subservient to the same function. These sacs communicate directly with the gastric cavities by means of openings in the membranous partitions which separate them. The partitions bear on their inferior surfaces, plaited membranes, which, under the microscope, present the appearance of being studded with vesicles containing a little watery fluid. A row of filamentary organs is also attached to these membranes, which move like external cilia, even for some time after they have been removed from the body of the animal.

VI. *Secretion.*—The existence of this function in the acalephæ is made known to us by the emission from their bodies, under certain circumstances, of a glairy mucus; by the stinging effect which some unknown product of their organization has upon our skin; and by the remarkable phenomenon of luminousness, which a large number of them present. The organs by which the mucus is secreted have not been satisfactorily observed. Dr. Milne Edwards saw reason to conclude with regard to the rhizostoma, that a large quantity of this fluid is secreted by a glandular structure situated along the margins of the arms. The stinging property possessed by several animals of this class has been the subject of inquiry since the time of Aristotle, but to this day we remain in doubt with regard to the nature and mode of production of the agent which causes this effect. Some men seem to be insensible to the irritation generally produced by the contact of living acalephæ. But, for the most part, a slight touch of any part of their surface, and chiefly of the pendent tentacula, is followed within a few minutes, at most, by a burning pain, redness, swelling, and sometimes even a vesication, of all that portion of the skin which touched the animal. Sloane said of the physalus, ("what the seamen call caravels, or Portuguese men-of-war,") "They burn violently—they do suck themselves so close to the skin that they raise blisters, and cause sometimes St. Antony's fire."* Even on our own coasts, severe cases of inflammation of the skin are occasionally seen, which have been produced by the irritation received during bathing from some of the larger pulmograda. In physalus, the stinging property seems to reside chiefly in the fluid with which the tentacula are filled. It continues to act powerfully even after the organs containing it have been detached from the body. And not only so, but it is said by some observers that its peculiar properties are so permanent, that vessels in which the animals have been placed must be washed several times in water, and carefully scoured before they can be used without inconvenience. On one occasion it was found that linen, which had been merely rinsed in soap and water, had this quality of irritation fifteen days after it had been used in making observations on the physalus.* None of the cirrigrada hitherto examined possess the stinging property.

The organs by which the luminous matter is elaborated are unknown. In some species, it is evidently mixed with the mucous fluid, which is so abundantly poured out from the margins of the arms and the disc. It has been frequently observed that the ciliograda are luminous chiefly along their rows of cilia, and that these continue to emit light for some time after their removal from the body. Perhaps the greater number of the acalephæ are luminous. According to Dr. M'Culloch, all inhabiting the British seas are so; and indeed it is chiefly to the emission of light by animals of this class that the beautiful phenomenon of the luminousness of the sea is owing in all situations. Spallanzani, however, whose observations and experiments on this subject were as extensive as they were careful and ingenious, came to the conclusion that "the medusæ which are possessed of luminous properties are extremely few compared with those which are destitute of it." The same philosopher remarked, with regard to some of the pulmograda, that they emit light more strongly during the contractions of their disc than at other times; that the intensity of their light increases when they are pressed in any way; that the luminousness resides chiefly in a peculiar fluid secreted by glands situated around the margins of the disc, along the edges of the tentacula, and in the fringed partitions of the gastric cavities; that this fluid being mixed with other fluids, as with fresh and salt water, and especially cow's milk, imparts its luminousness to them; that when spread over solid bodies it continues to shine for several minutes; and that in it there generally exists that irritating substance which produces the stinging effect. Spallanzani applied some of this fluid on two occasions to the tip of his tongue. It excited a burning sensation, which lasted more than a day. A similar feeling, but much more painful, followed the accidental application of a single drop of the same fluid to the conjunctiva.† In most of the acalephæ, the external covering is very fine, smooth, and delicate; but sometimes it is granular, or even warty. It does not appear that these differences in its structure have been observed by any naturalist to be connected with corresponding differences in the power of emitting light. (See LUMINOUSNESS, ANIMAL.)

VII. *Generation.*—The organs of this function cannot always be satisfactorily ascertained. This may, in a great measure, be owing to their minuteness and transparency when not in action. Ovaria and oviducts, however, are distinctly seen in several species; but no other organs connected with the generative function have hitherto been discovered. According to Eschscholtz, the ovaria in the physograda consist of several groups of vesicles and filaments,

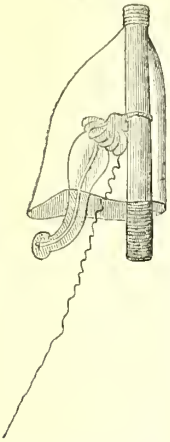
* Nat. Hist. of Jamaica, ii. p. 273. Sloane recommends acajou oil as "*the* remedy for the stinging of this nettle." Mr. Bennett has lately found (Lond. Med. Gaz. xiv. 908.) that the application of vinegar to the irritated surface in some degree alleviates the pain.

* Journ. Roy. Inst. 1831, p. 205.

† Travels in the two Sicilies, iv. 250.

loosely attached to the lower surface of the air-bladder. In the diphyda, they are in the form of numerous vesicles, having thick tunics filled with an opaque white fluid, and situated within one of their swimming organs. Such parts were seen by Eschscholtz only in some individuals, and on this account he was disposed to regard them as ovaries. But Messrs. Quoy and Gaimard seem to consider it more probable that the minute botryoidal bunches of vesicles, which surround the base of each sucker on the lengthened filaments, (before alluded to as being subservient both to nutrition and to locomotion,) are the ovaries.*

Fig. 13.



A portion of the ovigerous filament of Diphyes much magnified.

It does not appear that either Eschscholtz or Messrs. Quoy and Gaimard saw the ova.

In the ciliograda, the ovaries are more obvious. They consist of two or four vesicular organs, each placed between two of the cilia-bearing arches. In cydippe, they are of a red colour, and nearly cylindrical shape. The ova are spherical.

The parts in the pulmograda corresponding to the organs just referred to, are eight round bodies, of small size, situated near the margin of the disc, each formed of a vesicle, containing, at its free extremity, many minute hexagonal corpuscules; there is attached to each vesicle a digitated appendix, which seems to be hollow, and to communicate with the circular vessel. These organs were seen by Gaede and by Müller in *medusa capillata*, and *M. aurita*, and by Eschscholtz in some species of *cyanea*, *sthenonia*, *pelagia*, and *chrysaora*; Dr. M. Edwards has observed them also, at certain seasons, in *rhizostoma*; and in *carybdea marsupialis*, he found, midway between each pair of pendent filaments, and immediately above a little notch in the margin, four spots of a deep brown colour, each of which appeared, under the microscope, to be formed partly by a minute spherical body, having a granular aspect, as if it were filled with eggs, and partly by a little sac, with puckered sides, which is imbedded in the gelatinous substance of the body. These he regards as the ovaries.† But, notwithstanding their having found granular bodies like ova in the organs above described, neither Gaede nor Müller considered them as ovaries. Müller regarded the granules as excrementitious matters; and Gaede thought that he saw the ovaries in the plaited membranes of the gastric cavities; whence he observed the ova descend into certain minute vesicles imbedded in the margins of the arms. He remarked that, in *medusa aurita*, when the cells in the arms were filled with eggs, the plaited membranes had none; and, on the other hand, when there were no eggs in the arms, the plaited membranes were studded with them. Cuvier was also of opinion that the ova are formed in the plaited membranes above mentioned, and that they are matured in the margins of the arms.*

No observations, so far as we know, have hitherto been made on the development of the ova; but Dr. Grant has recently stated that the ova of *equorea* are furnished with cilia, and have locomotive powers, like the ova of the *porifera* and *polypifera*.† The colours of the acalephæ often depend on the tints of their ova: these are generally red, but sometimes brown, yellow, or purple.

VIII. *Geographical distribution.*—We conceive that a brief notice of this part of their natural history may, in some measure, illustrate the physiology of the acalephæ. They are met with in all seas; but certain families exist more abundantly in some localities than in others. The ciliograda and pulmograda, for instance, are inhabitants chiefly of the colder regions, while the physograda are seldom found beyond the limits of the tropical zone. Some float in bays, and near land, but the greater number in the high seas. *Medusæ* and *cyaneæ* are met with only in the cold and temperate zones of the northern hemisphere. *Cydippe* lives in the North Arctic Ocean, as well as in the Pacific, under the equator. One species of *cestum* inhabits the Mediterranean,—another the South Sea. It frequently happens that enormous numbers of one species are met with closely grouped together, so as somewhat to impede a ship's progress for two or three successive days; after which, not a single individual of the same species is seen. In the European seas, it is chiefly in summer and autumn that the acalephæ swim on the surface. In winter, they probably sink to the bottom.

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(John Coldstream.)

* Ann. des Sc. Nat. x. 8.
† Ann. des Sc. Nat. xxviii. 250.

* Règne Animal, second edit. iii. 277. See also Carus, Comp. Anat. ii. 307.
† Lectures, Lancet, No. 565. p. 483.

ACIDS, ANIMAL. Several acids are found in animal products, some of which are peculiar to organized bodies, and others common to them and to the other kingdoms in nature. The former are characterized by their analogy to other organic compounds, and are ternary or quaternary combinations of carbon, hydrogen, oxygen, and nitrogen. The latter are for the most part binary compounds, such as the phosphoric, carbonic, muriatic, sulphuric, and fluoric acids.

With the exception of lactic acid, the existence of which as a distinct definite compound is doubtful, there is only one acid which can strictly be called peculiar to animals, namely, the *uric acid*. The oxalic, benzoic, and acetic acids are common to animals and vegetables.

The other animal acids are not found ready formed, but are artificially produced by various chemical processes in which animal matters are concerned. Such are the various acids from fat and oil, the animal pyroacids, the purpuric acid,* and a few others. There are also certain acids almost peculiar to individual animals, such as the formic,† the allantoic or amniotic,‡ the bombic, &c.,§ and one or two which are the products of disease.

Under the articles FAT, URINE, MILK, and BONE, will be found the details respecting the principal animal acids.

(W. T. Brande.)

ACRITA (α, priv. κρινω, *discerno*,) a primary division of the animal kingdom founded by Virey, and so called by Macleay,|| composed of the lowest classes of the radiate animals of Cuvier, and characterised by an *indistinct*, diffused, or molecular condition of the nervous system.

The necessity for a dismemberment of the Radiata of Cuvier, which Rudolphi¶ justly calls a chaotic group, has been felt, and directly or indirectly expressed, by most naturalists and comparative anatomists.** It is impossible, indeed, to predicate a community of structure in either the locomotive, excretive, digestive, sensitive, or generative systems, with respect to this division, as it now stands in the "Règne Animal."

As in the animal organization the nervous system is that which is subject to the fewest varieties, and as its relative perfection is the surest indication of the relative perfection of the entire animal, the modifications of this system necessarily indicate the highest or primary divisions of the animal kingdom, and form their distinguishing characters.

Taking, then, the nervous system as a guide, the radiata of Cuvier will be found to resolve themselves into two natural groups, of which the first, composed of the *Polygastric Infusoria* of Ehrenberg, the *Polypi* of Cuvier, the *Entozoa parenchymatosa*, Cuv. or *Sterelmintha*, and the *Acalephæ*, differs in the absence or obscure traces of nervous filaments from the second division, including the *Echinoderma*, the *Entozoa cavitaria* or *Cœlelmintha*, the *epizoa*, and the *Rotifera*, Ehr., in which nervous filaments are always distinctly traceable, either radiating from an oral ring, or distributed, in a parallel longitudinal direction, according to the form of the body.

These different conditions of the nervous system are accompanied with corresponding modifications of the muscular, digestive, and vascular systems, and a negative character, applicable to the higher division of Cuvier's Radiata, may be derived from the generative system.

With respect to the muscular system, we find that although all the Acrita possess the locomotive faculty at some period of their existence, and many never become fixed, yet that distinct muscular fasciculi are not necessarily developed. In the fresh-water polype, for example, the whole of the homogeneous parenchyma of which it consists is equally contractile; and even in the medusa, which ranks among the highest of the Acrita, no distinct muscular organs for effecting the contractions of the gelatinous disc have yet been detected. In the higher division of radiata, on the other hand, which from the filamentous condition of the nervous system may be termed *Nematoneura*, the muscular system is always distinctly eliminated.

The difference in the condition of the digestive system between the Acrite and Nematoneurous classes is still more striking: in the former the alimentary canal is excavated in the parenchyma of the body, and is devoid of distinct parietes: in the Nematoneura it is provided with a proper muscular tunic, and floats in an abdominal cavity.

A corresponding difference is presented by these two divisions of the invertebrate animals, in the condition of the vascular system. Where traces of sanguiferous organs are met with in the Acrita, they are equally with the digestive organ devoid of proper parietes, but consist of reticulate canals in the substance of the body, generally situated near the surface, and in which a *cyclosis* of the nutrient fluids is observed analogous to that of plants, but not a true circulation. This structure obtains in the Acrita as low down in the scale as the polygastrica, in which class Ehrenberg has determined the existence of a superficial network of vessels containing an opaline fluid. In those

* First obtained by Dr. Prout from the pure lithic acid, of which the excrements of the boa constrictor consist.

† Procured from the expressed liquor of ants.

‡ Supposed by Vauquelin to exist in the liquor amnii of the cow.

§ Extracted by Chaussier from the silk-worm, but its existence is very problematical.

|| Horæ Entomologicæ, vol. i. pt. ii. p. 202.

¶ Synopsis Entozoorum, p. 572.

** Lamarck observes, "Les *animaux apathiques* (as he terms the *Acrita*) furent très-improprement appelés *zoophytes*: ils ne tiennent rien de la nature végétale, et tous généralemeut sont complétement des animaux. La dénomination *d'animaux rayonnés* ne leur convient pas plus que la précédente; car elle ne peut s'appliquer; qu'à une partie d'entr'eux; et il s'en trouve beaucoup parmi eux qui n'ont absolument rien de la forme rayonnante." Anim. sans Vertèbres i. p. 390.

genera of sterelmintha or parenchymatous intestinal worms which manifest traces of the circulating system, the fluids undulate in canals of a similar structure, as is displayed in the planariæ, and parasitic trematoda, and also in the echinorhynchi, in some species of which genus the cutaneous canals form a rich network.* In the acalephæ the condition of the vascular system is equally simple with that of the lowest Acrita, as is exemplified in the marginal reticulate canals in the disk of the rhizostoma. In the Nematoneura, on the contrary, those classes which manifest a circulating system distinct from the digestive tube, as the echinoderma and rotifera, possess vessels with proper parietes, distinguishable into arteries and veins.

No Nematoneurous class presents an example of generation by spontaneous fision or gemmation, but these modes of reproduction are common in the Acrite division.

The planariæ among the sterelmintha are capable of indefinite multiplication by simple division; and the medusæ are stated to produce, not ova, but ciliated locomotive gemmules or internal buds. The various examples of these plant-like modes of generation which the polypi and polygastrica present are familiar to most persons, and will be especially treated of under their respective articles.

The fissiparous and gemmiparous modes of reproduction are not, however, the exclusive modes by which the Acrite classes are perpetuated. Most of the sterelmintha are propagated by means of ova: in the *cystica* and *cestoidea*, the generative organs consist of ovaries alone, or are cryptandrous; in the trematoda, a fecundating gland is superadded to the ovary; while in the acanthocephala the sexes are separate, so that thus early in the animal kingdom, we find typified all the different modes of generation by which the race is continued in the higher classes of animals.

The different conditions of the important organic systems which are thus seen to obtain in the great group of animals called Radiata and Zoophyta fully justify a partition of the group corresponding with those differences. For the lower organized division we retain the name proposed by Macleay, but extend its application to the acalephæ; and thus constituted it may be characterized as follows.

Sub-kingdom Acrita.—*Gelatinous polymorphous animals, without distinct nervous fibre, or visceral cavities.*

Alimentary canal excavated in the parenchyma of the body, generally without an anus.

Sanguiferous system composed of reticulate canals without proper tunics.

Generation in most fissiparous or gemmiparous; in some oviparous.†

The Acrita have been termed *Protozoa*, as being on the first step of animal organization. They are analogous to the ova or germs of the higher classes, and have, therefore, been termed by Carus *Oozoa*; and as the changes of the embryo succeed each other with a rapidity proportionate to the proximity of the ovum to the commencement of its development, so also we find that in each class of Acrita there are genera which advance into close approximation with some one or other of the classes belonging to the higher divisions of the animal kingdom. It results, therefore, from this tendency to ascend in the scale of organization that there is greater difficulty in assigning constant or general organic characters to the Acrita than to any of the higher divisions of animals. Even in the nervous system, we find as we are led step by step from the hydra to the actinia in the class Polypi, that the nervous globules begin to manifest the filamentary arrangement about the oral orifice in the last named genus. That, again, in tracing the successive complication of the sterelmintha from the hydatid to the echinorhynchus we also come to perceive traces of longitudinal nervous filaments in the latter highly organized genus of parenchymatous worms. In the acalephæ the examples of the aggregate form of the nervous system would seem to be more numerous and distinct. Ehrenberg has detected what he considers as a nervous system in a gelatinous medusa; and Dr. Grant has recently described a nervous collar giving off simple filaments in the more highly organized beroë, which, in its distinct intestine and anal outlet, recedes too far from the medusidæ to be placed in a natural arrangement in the same class. Many of the polygastrica are endowed with simple visual organs or ocelli, in the form of red or yellow spots; similar organs of a dark colour are exhibited by the planariæ, and Nordmann also describes them in some internal parasitic trematoda. Ehrenberg has recently discovered coloured ocelli in a medusa, and he ascribes a sense of taste to the polygastrica.

The indications, however, of the special senses in the Acrita are feeble and obscure, and in the least doubtful instances the organs are evidently of the simplest and most elementary nature.

For the most part all the different systems seem blended together, and the homogeneous granular parenchyma possesses many functions in common.

Where a distinct organ is eliminated it is often repeated indefinitely in the same individual. Thus in the polypi the nutritious tubes of one individual are generally supplied by numerous mouths, and it has, consequently, the semblance

* Rudolphi terms one species *echinorhynchus vasculosus*, from this circumstance.—Synopsis Entozoorum, p. 581.

† The definition of the Acrita given by Macleay is confessedly a negative one as referred to animals; it is as follows:

"Animalia gelatinosa polymorpha, interaneis nullis medullaque indistincta.

"Os interdum indistinctum, sed nutritio absorptione externa vel interna semper sistit. Anus nullus.

"Reproductio fissipara vel gemmipara, gemmis modo exteris, modo internis, interdum acervatis.

"Pleraque ex individuis pluribus semper cohærentibus animalia composita sistunt."—Horæ Entomologicæ, ii. p. 224. *See also* Lamarck, Anim. sans Vertèbres, ii. p. 2.

of a composite animal; the polygastrica derive their name from an analogous multiplication of the digestive organ itself. Among the sterelmintha we find instances where the generative system is the subject of a similar repetition, each joint of the tæniæ being the seat of a separate ovary, though all are nourished by continuations of one simple system of nutritious tubes. The calcareous and siliceous sponges, again, which, in eliminating the first sketch of an internal earthy skeleton, seem to lose the few characteristics of animal life which they before possessed, are limited to the repetition of a simple spiculum.

The formative energies of the Acrita being thus expended on a few simple operations, and not concentrated on the perfect development of any single organ, it is not surprising that the different classes should exhibit the greatest diversity of external figure.* But it has been well observed that Nature, so far from forgetting order, has, at the commencement of her work, in these imperfect animals given us a sketch of the different forms which she intended afterwards to adopt for the whole animal kingdom. Thus in the soft, sluggish sterelmintha we have the outline of the mollusca; in the fleshy living mass which surrounds the earthy hollow axis of the polypi natantes, she has sketched a vertebrated animal; and in the crustaceous covering of the living mass, and the structure more or less articulated of the polypi vaginati we trace the form of the annulose or articulate classes.

(Richard Owen.)

ADHESION, (from *ad-hærere*, Lat. *adhesio*, Fr. *adherence*, Germ. *wiederanheilung*, Ital. *adesione*,) that process, by the occurrence of which, when two living surfaces, naturally or artificially separated the one from the other, are brought into mediate or immediate contact, and inflammation is developed, those surfaces may become adherent the one to the other.

This adhesion may be effected either by the intervention of a stratum of exhaled fibrino-albuminous matter, inorganic in the first instance, but at a subsequent period acquiring organization, and becoming a perfect and permanent cellular bond of union; or it may not occur until after suppuration has been established and granulating surfaces are presented; these surfaces enter into adhesion, and in this case the bond of union is not so decidedly cellular in character as in the former; it is more or less dense and fibro-cellular.

In either case, the medium of union presents peculiar modifications dependent upon the tissue on which it is developed. This circumstance, and especially the deposition of osseous matter, where bony union is required, was one of the strongest arguments used for the purpose of establishing the existence of the presiding intelligent principle of Stahl.

If the first process, that in which the fibrino-albuminous exhalation obtains, be interfered with, that is, if a more intense degree of inflammation be developed, such exhalation can no longer occur, but the second state, that in which a purulent exhalation shall be the product, may be induced.

It is upon this principle, viz. that a certain quantity of inflammation shall predispose to the first species of union, which is termed union by the first intention; and that a greater quantity may produce a purulent exhalation, and therefore be opposed to such union, that is founded the following precept. "When it is deemed prudent to prevent union by the *first intention*, we have merely to introduce between the surfaces, and retain there from eighteen to twenty-four hours a piece of lint, by which a sufficient degree of inflammation will, usually, be excited to ensure a suppurating surface."

From the time when the phenomena of inflammation were first carefully studied, until very recently, it has been commonly, if not universally maintained, that adhesion could never be accomplished in the absence of inflammation.

In the present day, Breschet* and some others have endeavoured to establish that adhesion does not, necessarily, imply the pre-existence or co-existence of inflammation; and as it appears to me upon very insufficient evidence. They say that adhesion may result from a "*primitive disposition of the organization*," and as evidence of the existence of this *disposition*, they refer to certain congenital affections, occlusion of the eyelids, and of the lachrymal canal, imperforations of the mouth, the anus, and so on. Why they should assume that phenomena, the mechanism of which appears identical, should be effected by a totally different agency in intra and in extra-uterine life, it is not easy to understand, and I believe such is not the fact.

We may have certain of these occlusions, accomplished in extra-uterine life, but never without the intervention of inflammation; and what possible reason have we for supposing that if these occlusions do commonly, nay always, occur in consequence of the development of inflammatory action, that this agency shall be wanting during uterine life? None, I apprehend, beyond simple assumption.

Imperforation of the eyelids and occlusion of the lachrymal canal differ from imperforation of the mouth and of the anus, in that the former result, not from the presence of an anomalous membrane, but only from the union of existing membranes, which are normally separated the one from the other. In the greater number of cases the eyelids are simply adherent, either at one or many points, or along the whole length of their border, and I would say are always so in consequence of inflammation.

The other imperforations to which allusion has been made, are dissimilar to those of the eyelids. Imperforation of canals opening upon the surface of the body is a case in which, almost always, there has been an arrest of development; all the canals which in the adult are lined by a mucous membrane, continuous with the skin at their orifice, are naturally, at

* Macleay, ibid, p. 123.

* Dict. de Méd. art. Adhérence.

a certain epoch of embryo life, imperforate. These organic states, which nosologists have so often considered as diseases, are, therefore, simply primitive conditions preserved by anomaly, and become permanent instead of transient.* It may, therefore, be inferred that the greater number of cases adduced as evidence of adhesion in intra-uterine life are not in point, and if they were it may still be asserted, and the assertion be borne out by analogy, that they had not occurred in the absence of inflammation.

John Hunter seems to have had the idea that adhesion may occur in the absence of inflammation in certain cases, namely, in those where blood has been effused, that this blood may become organized and form a bond of union. He says, " It does not seem necessary that *both* surfaces, which are to be united, should be in a state of inflammation for the purpose of effecting an union ; it appears *only necessary that one* should be in such a state, which is to furnish the materials, viz. to throw out the coagulating lymph, and the opposite uninflamed surface accepts simply of the union ; nor is it even necessary that *either* surface should be in a state of inflammation to admit of union: we often find adhesions of parts which can *hardly* be called inflamed."†

I believe that no solution of continuity can be obliterated in the absence of inflammation, the injury which has occasioned the solution of continuity, and the effusion of blood, being sufficient to excite inflammation. The only circumstance under which it seems to me to be possible that union could be produced in the absence of inflammation, is one which can only rarely occur; and even then, although the possibility of the occurrence can hardly be denied, its reality may be reasonably questioned. If a portion of blood, for instance, be effused into a serous cavity, its colouring matter is, after a time, removed, and a fibrino-albuminous coagulum remains. This coagulum coming in contact with a previously uninflamed serous membrane, may become united to this membrane: and it is believed by some pathologists that this union occurs without the supervention of inflammation. Another situation where it is believed by certain pathologists that union is produced by similar means, is in a portion of artery included between two ligatures, the blood which has been included between the two points undergoing a similar change to that which I have already described, and adhesion of the clot to the internal tunic of the artery being effected in the absence of inflammation.

Such cases may carry conviction to the mind of a superficial observer, but a more careful investigation will lead to an opposite conclusion. My own observations induce me to think, that of all the causes by which adhesive inflammation of serous membranes may be produced, the most remarkable perhaps is an extravasation of blood into their cavities, which appears to excite just the precise quantity of inflammation necessary for the production of adhesion. If we examine the point at which such coagula are maintained in contact with serous membranes, before perfect union is established, we shall find between the coagulum and the membranes a stratum of exhaled matter, the existence of which would lead to the conclusion that the clot has excited in the membrane as much inflammation as is necessary for the production of such exhalation.

In solutions of continuity where blood has been effused between the edges, it was maintained by John Hunter* that this blood was the provisional bond of union ; this, I apprehend, is not the case. Whether protected from the atmospheric air, which appears to exercise a very decided influence in decomposing it, as in some fractures, or directly exposed to it, as in ordinary solutions of continuity, this coagulum never, during the early periods, adheres with sufficient firmness to attach to each other the borders of a wound If, however, any portion of the coagulum remain after a fibrino-albuminous exhalation has been formed upon the divided surfaces, it may become in this way organised, and permanently adherent.

After the preceding remarks, it will therefore be held in this article that whenever an adhesion has been effected between two surfaces, naturally or artificially separated, that that adhesion must have taken place through the intervention of inflammation ; that inflammation arrived at a certain height will be accompanied by a fibrino-albuminous exhalation;—that if the inflammation be carried beyond that point, a purulent secretion may be established, and when this is developed, union, by what is termed the first intention, cannot occur ; granulations are then developed, and union by what is termed the second intention, may follow. The process by which each kind of union is effected I shall now proceed to describe in detail.

In all cases, whether two naturally separate tissues are to be united, or whether a solution of continuity is to be repaired, there appears to be a certain uniformity in the means by which the union is accomplished. Inflammation is developed, and a material susceptible of organization is exhaled, which becomes the connecting medium. This matter in its greatest state of simplicity is exuded under the form of *lymph*, upon the surface of the parts to be united ; it is coagulated, and transformed into a soft pulp ; it gradually increases in density, acquires a reticular or porous aspect, a first rudiment of organization, and as a second degree exhibits in its substance red spots, then striæ, which have the appearance of vascular ramifications, and at last bloodvessels.

It is hardly possible to collect this lymph in a state of purity except in the canal of an artery where it has been exhaled between two ligatures. It is then presented under the form of a whitish matter, of a soft and fibrinous consistence, which

* Isid. Geoff. St. Hilaire, Hist. des Anomalies de l'Organization, t. i. p. 532.

† On the Blood and Inflam. Ed. 1828, p. 319.

* Loc. cit. p. 253.

is rendered particularly evident when the lymph is submitted to the action of boiling water; it dissolves almost completely in a warm solution of caustic potash, though less promptly than thickened albumen, but more rapidly than fibrine.

This matter, which is probably the same with that by which all parts of the body are nourished and preserved, but in the case before us secreted in increased quantity and preserving a strong tendency to coagulate, has nothing in it which is necessarily opposed to the healthy action of the animal economy. In fact we may consider exudation as a nutrition, much exalted by inflammatory action, which is itself only an exaltation of the vital properties.

We may admit four periods or states of change to which this material which constitutes the medium of adhesion is subject—a first, the period of development; a second, a period of increase; a third, that of organization; and a fourth, that of mutation; in which it is changed into a cellular tissue.

In the first period, we find that in twenty-four, and sometimes even in nineteen hours after we have irritated a serous membrane, the pleura of a dog, or of a rabbit for instance, that this membrane is much injected, and that there has been formed upon its surface an extremely thin, pulpy stratum, which may very easily be removed: the second period commences when this exudation has assumed a membraniform appearance, and is characterized by an augmentation of thickness and of density: the third period is characterised by still greater density and the presence of vessels. Stoll believed that these membranes might become organised in twelve, nine, or even eight days after the invasion of the disease. Home believed that vessels might appear in twenty-four hours.

In the fourth period, the membrane loses some of its thickness, and every day assumes more and more of the appearance of cellular tissue; and when perfected, there is not only identity of appearance between cellular tissue and these membranes, but also, according to Laennec,* identity of use, and even of disease, except that this tissue very rarely contains adipose matter.†

Nothing in our subject is more curious or more important than the organisation of these membranes; their vessels are thin, delicate, and similar to those of the pia mater; their form and their direction are extremely simple; they are not tortuous, and they proceed, usually, in fasciculi, almost like the lymphatics of the extremities. We may easily convince ourselves that their formation is sometimes very prompt, by the perusal of the following case. A portion of strangulated intestine, which, after the incision of the herniary sac, did not present many bloodvessels, was examined after the death of the individual, which occurred in *twenty-nine hours* after the operation, by Sir Everard Home: he found the portion of intestine which had been strangulated profoundly inflamed, and covered in many points by a "layer of coagulable lymph:" this intestine was injected with very fine size, and two small bloodvessels were found passing along through the new membrane into which the injection had penetrated.

According to Laennec* we may observe the following phases in the organisation of these membranes.

The rudiments of bloodvessels are at first presented under the form of striæ of blood, which are more voluminous than the vessels by which they are to be succeeded. The blood appears to have penetrated into the tissue of the membrane, as if pushed by a strong injection; yet in examining the points of the membrane, on which the layer of "coagulable lymph" is deposited, we find no destruction, nor any orifice of a vessel, but only spots of blood. Soon, according to Laennec, "these lines of blood take a cylindrical form, and ramify in the manner of bloodvessels, still preserving a considerable diameter. If, at this epoch, we carefully examine them, we find that these vessels have an external coat which is soft, and formed of blood scarcely concrete, to which they owe their colour. After having incised this coat, we withdraw a sort of mould, or rounded fascicular body, whitish and fibrous, evidently formed of concrete fibrine, and of which the centre appears perforated and permeable to the blood. However small be the canal, it is these fibrous fasciculi which should, by thinning, form the tunics of the bloodvessels."

These delicate observations have not, so far as I know, been confirmed by other observers: those authors who have spoken of newly developed vessels, among whom we may name Hunter, Monro, Soëmmering, do not speak of this mode of development. Hunter and Home explain it differently; they say there is at first a formation of small ampullæ, containing only a colourless fluid: second, a union of these ampullæ, and production of a vascular network, not yet supplied with blood: third, an inosculation between the newly developed vessels, and those of the inflamed membrane, and next the ingress of blood. Beclard was of the same opinion.† Gendrin thinks that the new vessels are developed by the action of the primitive vessels; he says, "that the blood is excreted by the adjoining capillaries, opening into the soft and fibrinous tissue deposited in the inflamed part; this blood becomes concrete, and the vascular impulsion, *a tergo*, being continued, new blood is pushed into it and hollows it. Thus the little vascular rudiment is prolonged into an irregular, flexuous, and unequal stria, which meets another and unites with it, continuing in this way to prolong itself into the least resistent portion of the fibrinous deposition."‡

To some extent the opinions of Laennec and

* De l'Auscultation Médiate, tom. ii. p. 293.

† Laennec states that he has "quelquefois" seen fat developed in these cellular laminæ. Loc. cit.—Ed.

* Loc. cit.

† Anat. Générale, p. 195.

‡ Hist. Anat. des Inflam. tom. ii. § 1393. and 1571.

Gendrin are alike; they believe that the formation of the new vessel consisted in this, that the little clot was perforated, and that it was penetrated by liquid blood.

The experiments of Brande* would, however, lead to a different conclusion; he shewed that the air contained in the blood had much influence in the formation of bloodvessels. This air is carbonic acid gas, and its quantity appears to be nearly equal in the two kinds of blood; being estimated at a cubic inch for every ounce of blood. This gas may be separated from the blood by the air-pump, and it escapes with a kind of bubbling or effervescence, causing the ascent of the mercury in a barometer attached to the apparatus.

It has been remarked that during the coagulation of the blood, a large quantity of carbonic acid gas escapes; this coagulation, observed under the microscope, has shewn that the gas, by escaping in all directions, forms a net-work of canals, the branches of which anastomose with each other; and that this net-work preserves its form after desiccation. It has also been established that it is this gas which forms those canals in coagulated blood; because, if by means of the air-pump we deprive the blood of it, before it is coagulated, they do not occur.

Sir E. Home has even injected the vessels which were developed in the coagulum soon after the blood was taken from a vein. If the formation of new vessels occur even in a coagulum of blood removed from the living body, but preserving still a certain quantity of its heat, and of its vitality, with more reason might we expect that a similar phenomenon should obtain during life: and this fact has been demonstrated by experiments performed on a rabbit, in which had been produced a hemorrhage from a small branch of the mesenteric artery: after twenty-four hours, the coagulum which was formed was injected.

The formation of vessels in coagulated blood, by means of the carbonic acid gas which traverses it in all directions, is in perfect accordance with the observations which have been made by M. Bauer upon germinating wheat, which were instituted for the purpose of shewing the influence of the globule of air. These globules are manifested below a bud of mucilaginous substance; they push it forward, elongate it, and thus form a filament.

I do not, however, believe that either of these theories correctly explains the phenomenon.

It was for a long time believed that false membranes were never organised; that nature had given to the parts of our economy an almost unlimited power of development, but not the faculty of communicating life to the products of the circulation; that false membranes *appeared* to be organised only because they constituted a kind of frame-work through which vessels from the inflamed tissue *might* be prolonged: ulterior observations, however, have shewn that these media are really organised. We have no general rules as to the time when such organisation shall commence. It seems to be dependent upon inexplicable individual dispositions. It may, however, be remarked, that the greatest analogy exists between the mode of development of vessels in these media of adhesion and their mode of production in the membrane of the yolk in the chick, saving always this remarkable circumstance, namely, the inconstancy, the irregularity of the work of organisation in the former, and, on the contrary, the constancy and the regularity of the occurrence in the latter case.

These media are in fact secreted by a tissue, the vitality of which is exalted to a certain extent, and it appears to impress upon the product of its secretion a commencement of vitality, as in generation. All these circumstances appear to me to demonstrate that these vessels are the product of a spontaneous generation—a true epigenesis; so indeed, to a certain extent, thought Hunter. He says, "In a vast number of instances I have observed, that in the substance of the extravasation there were a great number of spots of red blood, so that it looked mottled. The same appearance was very observable on the surface of separation between the old substance and the new, a good deal like petechial spots. Was this blood extravasated along with the coagulating lymph? In this case I should rather have supposed it would have been more diffused. I have therefore suspected parts have the power of making vessels, and red blood, independent of the circulation."*

If the inflammation be not strictly confined to that state in which the albumino-fibrinous exhalation is accomplished, but proceeds to the next stage, the exhalation entirely changes character; pus is produced, a granulating surface is developed, and union is accomplished by the intervention of another tissue, and by a slower process than that which we have already described. This is the process which is always observed in mucous membranes, scarcely ever in serous; for in the former, the albumino-fibrinous matter never becomes organised, and can therefore never be the medium of a permanent union. In these membranes, if adhesion occur, the inflammation must proceed to the succeeding stage. Adhesion of mucous membranes, however, does not often occur—it is not compatible with the performance of their functions.

Soon after the secretion of pus is established granulations are developed, and a state favourable to adhesion is produced. The development of granulations occurs in the following manner:—upon the surface, about to suppurate, is exuded a layer of "coagulable lymph;" this lymph becomes penetrated by bloodvessels, nerves, and absorbents, which give birth to granulations. These granulations are developed much earlier in some tissues than in others—in a stump, for instance, we see them first upon the cellular tissue, then upon the muscular, then the fibrous, and lastly upon the osseous tissue: they appear to form as much

* Phil. Trans. 1818. pp. 172 and 185.

* Loc. cit. pp. 388-9.

more readily as the tissue may be more cellular and vascular. That these organs are very vascular is evident from the rapidity with which they bleed upon the slightest contact; that they contain nerves is shewn by the pain which is produced in them by the slighest touch: does not their prompt destruction by slight causes seem to indicate the existence of absorbents?

No one has made more interesting researches into the nature of these bodies than Sir Everard Home.* He carefully observed the changes which occurred in an ulcer of the leg. By using a lens which enlarged objects eight times, he saw that granulations were formed in the following manner: first, is seen a mass of capillary vessels differently arranged; secondly, small sinuosities containing pus. The ulcer observed during ten minutes, offered, in the first place, an extremely thin and transparent pellicle, under which were disengaged globules of gas, then canals having a horizontal direction, and containing blood. The tunics of these vessels were so delicate that they were ruptured by the simple motion of the leg. These canals anastomose with each other, taking different directions; those which are developed the first were the next day changed into true vessels. Soon these new vessels have enough of solidity to admit of our passing a needle under them and raising without rupturing them. The formation of all these parts is due, according to Home, to the coagulation of pus, and the development of carbonic acid gas; "for if the puriform matter be wiped off, these phenomena are not produced." When, on the contrary, he employed substances, calculated to coagulate the pus, the formation of those vessels was accelerated. He concludes from his experiments that bloodvessels are developed, almost as it were under the eye of the observer; that they are not a prolongation of pre-existing vessels; that they are formed independently of the action of the subjacent solid parts. So far, therefore, although the processes may differ, yet the general points of union between the two modes is singularly similar.

While suppuration is proceeding, another operation is in progress under the layer of granulations. A stratum of cellular tissue, at first simple and not very resistent, afterwards fibrocellular, and lastly fibrous, is organised insensibly to serve as the base of the succeeding medium of union.

When granular surfaces are brought into contact, and the tendency to secrete pus has ceased, they enter into adhesion. This tendency is marked by a diminution of activity in the granulations; the membrane ceases to secrete pus, and the granulations become firmer and contracted: before union can be effected, the suppurating surface must, therefore, change its nature—must be destroyed. A state like that in simple union by the first intention is produced; the secretion becomes plastic, and somewhat analogous to that which accompanies that mode of union.

* Home on Ulcers.

When these new tissues or media of union are developed between surfaces naturally free, the structure of the two portions of the organ between which they are seated becomes changed. In serous or mucous membranes, as well as in those surfaces which are immediate modifications of these two systems, this may be observed. When, for example, the pleura costalis becomes adherent to the pleura pulmonalis, the point of union is no longer a serous membrane; the free surface having disappeared, an uninterrupted continuity is established between the subserous cellular tissue of the pleura costalis, and the interlobular cellular tissue of the lung. This conversion is frequent in the peritoneum; in the tunica vaginalis a similar effect is produced by the common operation for hydrocele; in synovial membranes a similar effect occurs in what is termed false ankylosis.

Having described the general laws by which the phenomena of adhesion are governed, I shall now point out, generally, the modifications which are impressed upon it in different tissues.

It is upon serous membranes that we may with most advantage study the process of adhesion, not only because it is more rapidly developed there, but because it much more frequently occurs there than in other tissues. If we examine the surfaces of two such membranes which have been recently united, commencing at a certain distance from the point of adhesion, we see the layer of coagulable matter effused between the two surfaces become thinner as we approach the point of contact. If the adhesion be sufficiently recent to admit of our separating the surfaces, we see the intermediate layer tearing, but remaining adherent to the inflamed surfaces. If the inflammation be more advanced, and the pseudo-membrane be more dense and organised, we find that the very thin layer of new deposition by which the union has place is more resistent than the thicker layer of organisable matter by which it is surrounded; and at a later period we may discover vascular filaments attaching the adherent portion of the new tissue to that upon which it has been developed. These filaments are as much more evident as the adhesion is more immediate: of this we may very easily assure ourselves by cutting transversely two portions of digestive tube which have become to a certain extent adherent by their external tunic. The adhesion may be already very solid at the points where contact is so immediate that we can scarcely distinguish the interposed matter. Very delicate red capillaries creep through this matter, whilst perhaps at the distance of some lines, and even at the centre of an already organised point, the contact having been less immediate, a plastic layer of one, two, or more lines in thickness, may be seen uniting the surfaces, but not presenting either the solidity or the organisation of the excessively thin layer which adjoins it.

When these adhesions have existed for a certain time, the serous structure completely disappears. This destruction of serous membranes at the adherent point is very evident around herniæ which have been inflamed; the intestines engaged in the tumour are enveloped by a more or less dense layer of cellular tissue; and hence many herniæ thus circumstanced have been described as having no hernial sac. This sac has, however, originally existed, but has disappeared by the adhesions which have been formed between it and the displaced organs, adhesions by which the cellular tissue which replaces the serous membrane has been developed.

If we consider these adhesions in relation to their frequency in the serous cavities, we see that they exist most frequently in the pleura, existing in nearly half the adult bodies examined. After the pleura comes the peritoneum, then the pericardium; those of the tunica vaginalis are less common, but the arachnoid is, of all serous membranes, especially relative to its extent, that where these adhesions are most unfrequent.

The absence of mobility appears singularly to favour this phenomenon: thus in the pleura they most frequently occupy the superior parts, and in the peritoneum most frequently occur between the viscera forming a hernia, and between the convex surface of the liver and the diaphragm.

The membranes between which such adhesions occur, must usually, of course, be in intimate relation, the one with the other during the time when the process is in progress of accomplishment, though now and then the distance is considerable; but they may afterwards become separated to great distances: those cellular bands which are so commonly seen in the thorax are evidences of this fact.

Some circumstances tend to demonstrate that these bands in serous structure may at a certain period of their existence be absorbed and disappear, and the secreting surface be reproduced. M. Ribes states that occasionally we do not find any trace of such bands, nor any adhesion in the peritoneum of persons who have had penetrating wounds of the abdomen. Beclard examined an insane person who had several times stabbed himself in the abdomen. At the points where the more recent of these wounds had been inflicted considerable adhesions were found; beneath the older cicatrices no vestige of adhesion was found. A case of artificial anus occurred in the practice of M. Dupuytren, by which fæcal matter passed during twelve days. The patient died at the end of seven months. At the examination after death, it was found that the portion of intestine in which the accidental opening had existed, was distant from the abdominal cicatrix between four and five inches. A very attenuated cellular band extended from the cicatrix to the portion of intestine. Doubtless a short time would have sufficed for the absorption of this band, when the intestine would have been set at liberty and the serous surface restored.

In the course of lectures which Bichat delivered only a few months before his death, he maintained that adhesion was never produced between mucous surfaces, and that consequently the cavities lined by this tissue were never obliterated. Few statements have given rise to more extensive discussion than this; few discussions have up to the present moment been attended by less satisfactory results. In his first dictum I believe he was clearly right, in the second as clearly wrong.

Mr. Hunter's opinion was in accordance with that of Bichat: he says, "that in all the outlets of the body called mucous membranes, the order of inflammation differs from that which occurs in cellular membrane, or in circumscribed cavities. In these latter adhesive inflammation is immediately admitted to exclude, if possible, suppuration." In internal canals, where adhesions would in most cases prove hurtful, the parts run immediately into the suppurative inflammation, the adhesive inflammation being in common excluded.*

Mucous membranes, when unchanged by disease, are not capable of becoming adherent the one to the other, and the reason of this is simple. I have already stated that no permanent adhesion can occur in the living body without the intervention of a new tissue, which at a certain indefinite or undetermined period of its existence becomes organized.

A pseudo-membrane of considerable extent may be thrown out upon an inflamed mucous surface; but this membrane, I apprehend, never becomes organised, and union between mucous surfaces cannot therefore be permanent unless some other agency be called into action. But, as soon as inflammation has destroyed the characters from which these membranes derive their name; when the mucus, which like an inorganic layer appears to oppose itself so successfully against immediate contact, thereby preventing the organization of the effused matter, no longer exists; when the cellular element which forms the basis of this membrane is developed, then adhesion by means of the union of granular surfaces is effected with the greatest facility; of this we have evidence in most of the mucous canals. It is not rare, for instance, to meet with complete obliteration of the vagina, of the cystic duct, and so on.

It is stated very generally that the opinion of Bichat is entirely unfounded; that inflammation of the vagina is followed by complete occlusion, without destruction or transformation of the mucous membrane, and that similar effects may occur in the Fallopian tubes, the uterus, and other mucous canals. That these are produced is perfectly true, but never until the disorganization to which I have alluded has occurred.

It is maintained triumphantly as a confirmation of the opinion that no transformation occurs, that when these adhesions are separated, we have the healthy mucous membrane performing its functions as before. This, however, is not the case; the membrane is essentially different, and it is not without difficulty that we can overcome its tendency to enter into adhesion again. That a membrane is produced, which performs functions analogous to

* Loc. cit. p. 305.

the primitive membrane, is true. If we examine a fistulous canal which has existed for a certain time, we find it invested by a membrane similar in appearance, and performing an analogous function to the primitive mucous membrane,—so rapidly does nature under certain circumstances adapt an organ to the performance of the function to which it is destined.

As it is therefore upon the organization of this pseudo-membrane that the species of union of which I am treating is dependent, some remark upon that subject becomes necessary. It has been maintained by Albers, Soemmering, and Larrey, that these new formations upon mucous membranes may become organized. The former of these gentlemen believes that the false membrane of croup is commonly organized. Soemmering, it is said, possessed preparations which demonstrated the fact. Cailleau* supports this opinion, as well as Villermé† and Guersent.‡ I have never seen this membrane present the slightest vestige of organization, nor have I ever found any one, with the exceptions I have named, who has, although, to my knowledge, they have been sought for during many years, by a number of the most competent observers of the present day. And as I believe the investigations of morbid phenomena are more accurately made at present than at any former period, I adhere to the opinion that organization of these membranes upon mucous surfaces never occurs; and that union by "the first intention" can never occur in those canals which are invested by mucous membrane. But when the composition of the mucous membrane becomes destroyed or disorganized by inflammation, and a granular surface is presented, adhesion may be and is frequently produced.

The epidermis with which the skin is furnished forms an inorganic stratum which is opposed to all adhesion; but remove this epidermis, render the surface bleeding, or suppurating, and adhesion may be produced with the greatest facility. It is against this tendency we have constantly to struggle for the purpose of preventing the adhesion of fingers to each other, to the palm of the hand, and so on,—so common a consequence of burns. Adhesion may in this tissue occur, therefore, by the development of the fibrino-albuminous medium, or by that of granulations. The synovial membrane of joints may become adherent, constituting a species of ankylosis, which is termed "false." In these cases the secretion of synovia diminishes and ultimately ceases, the contiguous surfaces lose their polish, become rugous, and contract adhesions. (See Joints.) In osseous tissues, adhesion may be effected either through the agency of the albumino-fibrinous exhalation already described, or that of granulations. (See Bone.) In cartilaginous tissues the mechanism of adhesion is different; and in speaking of the process in these tissues, it is necessary to divide the tissue into those which are invested by a more or less dense fibrous perichondrium, and those which are without it. To the first appertain the cartilages of the ribs, of the larynx, and all those which Bichat termed fibro-cartilages. The second class comprehend the diarthrodial. It is in fact, I believe, upon the presence or absence of the perichondrium, that are dependent the principal differences which are presented in the pathological condition of these organs. The non-diarthrodial as well as the fibro-cartilages, when they are ruptured or divided, are not united by a cartilaginous substance.

In the wounds of cartilages, with loss of substance, there is formed a kind of cellulous matter, which is a secretion from the perichondrium; in fact no phenomena of reproduction are observed where this membrane does not exist; thus it is never observed in diarthrodial cartilages. We may cut and mutilate these latter, and after many days we shall find the wound almost as it was on the first day. When the cartilages of the ribs are ruptured, their union is often effected by an osseous ring which surrounds the two fragments. See the articles Artery, Encephalon, Nerve, Fibrous tissue, Muscle, Vein, for the phenomena of adhesion in these structures.

* Rapport du Concours sur le Croup.
† Dict. des Sc. Méd. tom. xxxii. p. 260.
‡ Dict. de Méd art. Croup.

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(Benjamin Phillips.)

ADIPOCERE, from *adeps* and *cera:* a term given to a peculiar fatty matter, somewhat resembling spermaceti in appearance, and supposed to partake of the properties of fat and wax. In the year 1789, Fourcroy communicated to the Royal Academy of Sciences at Paris a curious account of the changes sustained by the human bodies interred in the cemetery of the Innocents in that city; some of these had been piled, for a succession of years, closely upon each other, in large cavities containing from one thousand to fifteen hundred individuals. One of these graves, opened in Fourcroy's presence, had been full, and closed for fifteen years. When the coffins were opened, the bodies appeared shrunk and flattened, and the soft solids were converted into a brittle cheesy matter, which softened and felt greasy when rubbed between the fingers. The bones were brittle; and the texture of the abdominal and thoracic viscera no longer discernible, but lumps of fatty matter occupied their places.

It is not uncommon to find masses of this adipocere in the refuse of dissecting-rooms, especially when heaps of such offal are thrown into pits and wells, and suffered gradually to decay. The carcases of cats and dogs and other drowned animals also often exhibit more or less of a similar change; and Dr. Gibbes (Phil. Trans. 1794) found that lean beef, secured in a running stream, underwent a change into fat in the course of three weeks. Fat, and the adipose parts of animals, also undergo a change in appearance and composition under similar circumstances: tallow becomes brittle and pulverulent, and may be rubbed between the fingers into a white soapy powder.*

Gay Lussac, Chevreul, and some other eminent chemists, conceive that muscular fibre, skin, &c. is not convertible into adipocere, but that this compound results entirely from the fat originally present in the substance, and that the fibrin is completely destroyed by putrefaction. There are cases, however, in which the conversion of muscle and of fibrin into fat can scarcely be doubted, (Annals of Philosophy, xii. 41,) though the propriety of applying the term *adipocere* to such fatty matter may be questionable. The action of very dilute nitric acid upon some of the modifications of albumen is also attended by their conversion into an adipose substance.

The chemical properties usually ascribed to adipocere are the following: it fuses at a temperature below 100°; it dissolves in boiling alcohol, and the greater portion is deposited as the solution cools; the action of ether resembles that of alcohol; it is saponified by the fixed alkalies, but not by ammonia. It would appear, however, from Chevreul's experiments, that adipocere is not a mere modification of fat, or a simple product, but that it is a *soap* composed of margaric acid and ammonia. These combinations of adipose substances and their further chemical history will be given under the article Fat.

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(W. T. Brande.)

* If a portion of the fatty degeneration of the liver be immersed for some time in water, it will furnish an excellent specimen of adipocere. The writer of this note had lately an opportunity of observing the process of the conversion of a large portion of liver into this substance.—R. B. T.

ADIPOSE TISSUE.—(Lat. *Tela adiposa* Fr. *tissu adipeux, tissu graisseux*, Germ. *das Fett*, Ital. *adipe*.

Many of the old anatomists, as Mondini, Berenger, Vesalius, and Spigelius, represent the fat *(adeps vel pinguedo)* of the animal body as entirely distinct from the *membrana carnosa*, or cellular membrane. The separate existence of a proper adipose membrane, however, situate between the skin and the filamentous tissue, or *membrana carnosa*, was first taught by Malpighi, then distinctly maintained by De Bergen and Morgagni, and finally demonstrated by William Hunter. Collins, James Keill, and other anatomists adopted the views of Malpighi, and Haller was disposed latterly to imitate De Bergen and Morgagni, in assigning to the fat of the animal body a situation distinct from that of the cellular membrane. And in this country the independent existence of the adipose membrane was recognized by Bromfield, John Hunter, and others.

It was still, however, confounded with that of the filamentous tissue under the general name of cellular membrane, adipose membrane, and cellular fat, by Winslow, Dionis, Portal, Sabatier, Bichat, and Meckel, and described as a variety or modification of the cellular membrane; and Blumenbach considers it as a secretion into that membrane. Its distinct existence from the cellular membrane was finally admitted by M. Beclard, and its anatomical and physiological relations as well as its chemical properties have been since minutely investigated by M. Raspail.

According to the dissections of De Bergen and Morgagni, the demonstrations of Hunter, and the observations of M. Beclard, the structure of the adipose membrane consists of rounded packets or parcels *(pelotons)* separated from each other by furrows of various depth, of a figure irregularly ovoidal, or spheroidal, varying in diameter from a line to half an inch, according to the degree of obesity in the part submitted to examination. Each packet is composed of small spheroidal particles which may be easily separated by dissection, and which are said to consist of an assemblage of vesicular bags still more minute, aggregated together by very delicate filamentous tissue. These were originally described by Malpighi under the name of membranous *sacculi*, and by Morgagni under that of *sacculi pinguedinosi*.

The appearance of these ultimate vesicular pouches is minutely described by Wolff in the subcutaneous fat, and by Clopton Havers* and the first Monro in the marrow of bones, in which the two last authors compare them to strings of minute pearls. If the fat with which these vesicles are generally distended should disappear, as happens in dropsy, consumption, chronic dysentery, and other wasting diseases, the vesicular sacs collapse, their cavity is obliterated, and they are confounded with the con-

* Osteologia Nova, Lond. 1691, and Obs. Nov. de Ossibus, Amst. 1731.

tiguous cellular tissue without leaving any trace of their existence.

Hunter, however, asserts that in such circumstances the cellular tissue differs from the tissue of adipose vesicles in containing no similar cavities, remarks that the latter is much more fleshy and ligamentous than the filamentous tissue, and contends that though the adipose vesicles are empty and collapsed, they still exist. When the skin is dissected from the adipose membrane, it is always possible to distinguish the latter from the filamentous tissue, even if it contain no fat, by the toughness of its fibres and the coarseness of the web which they make.

The distinguishing characters between the cellular or filamentous and the adipose tissue may be stated in the following manner. First, the vesicles of the adipose membrane are closed all round, and, unlike the cellular tissue, they cannot be generally penetrated by fluids which are made to enter them. If the temperature of a portion of adipose membrane be raised by means of warm water to the liquefying point of the contents, they will remain unmoved so long as the structure of the vesicles is not injured by the heat. If again an adipose packet be exposed to a solar heat of 104° Fahrenheit, though the fat be completely liquefied, not a drop will escape until the vesicles are divided or otherwise opened, when it appears in abundance. The adipose matter, therefore, though fluid or semifluid in the living body, does not, like dropsical infiltration, obey the impulse of gravity. Secondly, the adipose vesicles do not form, like cellular tissue, a continuous whole, but are simply in mutual contiguity. This arrangement is demonstrated by actual inspection, but becomes more conspicuous in the case of dropsical effusions, when the filamentous tissue interposed between the adipose molecules is completely infiltrated while the latter are entirely unaffected. Thirdly, the anatomical situation of the adipose tissue is different from that of the filamentous tissue. The former is found, 1st, in a considerable layer extended immediately beneath the skin; 2dly, in the trunk and extremities round the large vessels and nerves; 3dly, between the serous and muscular tissues of the heart; 4thly, between the peritoneal folds which form the *omentum* and mesentery; 5thly, round each kidney; and, 6thly, in certain folds of the synovial membranes without the articular capsules.

In each of these situations it varies in quantity and physical properties. In the least corpulent persons a portion of fat is deposited in the adipose membrane of the cheeks, orbits, palms of the hands, soles of the feet, pulp of the fingers and toes, flexures of the joints, round the kidney, beneath the cardiac serous membrane, and between the layers of the mesentery and *omentum*. In the more corpulent, and chiefly in females, it is found not merely in these situations, but extended in a layer of some thickness, almost uniformly over the whole person; but is very abundant in the neck, breasts, belly, *mons Veneris*, and flexures of the joints.

It has been long observed that the subcutaneous adipose layer presents considerable differences from the adipose matter found between the folds of the serous membranes; and the older anatomists, aware of these differences, distinguished the former by the name of *pinguedo*, and the latter by that of *sebum*. The subcutaneous adipose membrane is, when viewed as a whole, more elastic, softer, and less granular than the omental fat, and evidently presents the arrangement of vesicular bags much more distinctly than the omental. It is in the subcutaneous adipose membrane indeed, almost exclusively, that the vesicular arrangement can be recognized. The subcutaneous cellular fat also contains a greater quantity of oil than the omental, which abounds chiefly in firm, brittle, granular fat.

The situation where the vesicular structure of the adipose membrane is most easily demonstrated is in the hips between the skin and the gluteal muscles, and at the flexures of the joints generally. In the former situation especially, the constituent fibres of the vesicular bags are tough, firm, and ligamentous, and the bags themselves are large and distinct.

It is a remarkable anatomical character of the sebaceous or tallow-like fat that its distribution is confined chiefly to the external or commutual surfaces of several of the serous membranes; and this arrangement presents a series of interesting anatomical analogies. Thus sebaceous fat is found on the external surface of the *pleura costalis*, between it and the intercostal muscles, and between the layers at the posterior and anterior *mediastinum*. It is also found between the cardiac *pericardium* and the muscular substance of the heart, especially around the vessels of the organ. In some of the large mammalia even this circumstance is connected with peculiar anatomical appearances. Thus, in the heart of the dolphin *(delphinus tursio)* we find the cardiac pericardium formed into broad prominent fringes, consisting each of two folds of the membrane, between which is interposed a considerable quantity of sebaceous fat. In the same manner the several *omenta*, or peritoneal duplicatures in the abdomen, may be recognized as analogous fringes containing more or less sebaceous fat; and the omental appendages *(appendices epiploicæ)* of the colon must be regarded as examples of the same arrangement. Lastly, in the interior of the articular capsules we find the synovial membranes forming large prominent fringes, which, if immersed in water, show to what extent they are made to recede from the capsule and bone, and forming cavities of duplication in which sebaceous matter is contained.

It thus appears that none of the serous membranes is exactly applied either to the *parietes* of cavities or to the surface of the contained organs, but that they form intervals on their outer or attached surfaces, on which various quantities of sebaceous fat are deposited. In all these substances we do not recognize the same distinct arrangement of an appropriate organ, but simply masses of adipose, or rather sebaceous matter, interposed between the attached surface of the serous membranes and the adjoining or the contained organs.

Fat occurs in a third modification in the marrow of bones. The adipose granules, which are soft, whitish-yellow, and oleaginous, are here contained in a peculiar membrano-cellular web, forming numerous vesicles, which may be regarded as an ultra-osseous adipose tissue. It is a remarkable proof of the influence of the vital principle that during life the substance of the bones is never tinged with this animal oil, but the moment life is extinct, the marrow begins to transude and impart to the bones a yellow tint and a greasy aspect.

Fat, though chiefly observed to occur in the bodies of animals, is nevertheless not confined solely to these bodies. Thus not only do various kinds of oil and consistent oleaginous matter occur in certain vegetables, but substances similar even to tallow are found in some vegetable productions. A sort of tallow is obtained from the *vateria Indica*, a forest-tree of the camphor family, indigenous in the Indian Archipelago. In a species of croton indigenous in China, namely, the *croton sebiferum* of Linnæus, the *stillingia* of Michaux, or tallow-tree, the seeds are covered with a quantity of fat, bearing so close a resemblance in all its properties to tallow, that it is used by the Chinese in the manufacture of candles; and the fruits of the *aleurites triloba*, a native of the Sandwich Islands, of the same natural family with the *croton*, are the candle-nuts of the inhabitants of these remote regions.

It is chiefly in the subcutaneous layer that the organization of the adipose membrane has been investigated. The constituent vesicles or bags consist of firm, tenacious, ligamentous, gray, or whitish-gray coloured substance, mutually united by means of delicate filamentous tissue. These vesicles or sacs receive arterial and venous branches, the arrangement of which has been described by various authors, from Malpighi, who gave the first accurate account, to Mascagni, to whom we are indebted for the most recent. According to Malpighi,* the bloodvessels divide into minute ramifications, to the extremities of which are attached the membranous sacs, containing the globules of fat so as to bear some resemblance to the leaves attached to the footstalks of trees. These vesicular or saccular arteries are afterwards divided into more minute vessels, which then form upon the vesicular sacs a delicate vascular network. According to Mascagni, who represents these vessels in accurate delineations, the furrow or space between each packet contains an artery and vein, which, being subdivided, penetrates between minute grains or adipose particles, of which the packet is composed, and furnishes each component granule with a small artery and vein. The effect of this arrangement is that each individual grain or adipose particle is supported by its artery and vein as by a footstalk or peduncle, and those of the same packet are kept together not only by contact, but by the community of ramifications from the same vessel. These grains are so closely attached that Mascagni, who examined them with a good lens, compares them to a cluster of fish-spawn. Grutzmacher found much the same arrangement in the grains and vesicles of the marrow of bones.*

It has been supposed that the adipose tissue receives nervous filaments; and Mascagni conceives he has demonstrated its lymphatics. Both points, however, are so problematical, that of neither of these tissues is the distribution known.

The substance contained in these vesicles is entirely inorganic. Always solid in the dead body, it has been represented as being fluid during life, by Winslow, Haller, Portal, Bichat, and most authors on anatomy. The last writer, indeed, states that under the skin it is more consistent, and that in various living animals he never found it so fluid as is represented. The truth is that in the human body, and in most mammiferous animals during life, the fat is neither fluid nor semifluid. It is simply soft, yielding, and compressible, with a slight degree of transparency, or rather translucence. This is easily established by observing it during incisions through the adipose membrane, either in the human body or in the lower animals.

The internal or sebaceous fat, however, especially that interposed between the fat of the serous membranes, is much more consistent and solid. The reason of these differences will be understood from what is now to be stated regarding the proximate principles of animal fat.

The microscopical and atomical structure of fat has recently formed the subject of investigation by M. Raspail.† By placing a portion of lacerated fat upon a sieve, with an earthen vessel below it, and directing upon it a stream of water, numerous amylaceous granules are detached and pass through the sieve, and after falling to the bottom of the water afterwards rise to the surface, in the form of a crystalline powder, as white as snow. When these particles are collected by scumming, and dried, they form a starchy powder, though soft and somewhat oleaginous to the touch, and which does not reflect the light in a manner so crystalline as an amylaceous deposit does.

According to M. Raspail, when examined microscopically, these granules present forms and dimensions varying in different animals, in the same animal and even in animals of different ages, but in all clearly resembling grains of *fecula*. In the human body these particles are polyhedral and not susceptible of isolation. As they are more fluid also than in other animals, it is necessary to immerse the portion subjected to examination in nitric acid or *liquor potassæ*, either of which has the effect of consolidating the inclosed or central portion

* De Omento, Pinguedine, et Adiposis Ductibus, p. 41.

* De Ossium Medulla, Lips. 1758.

† Repertoire Générale d'Anat. 1827.

of each granule, and disintegrating the granules by the contraction of chemical agency. The borders of these granules appear by refracted light a little fringed—an effect which M. Raspail attributes to the corrosive action of the nitric acid.

When magnified to 100 diameters, they appear like irregular hexaedral or pentaedral bodies, from two to four lines in diameter, and all accurately fitted or conjoined to each other. The actual diameter of these granules in the adult human subject varies according to Raspail from .00117 to .00562 of an English inch. In youth and infancy they are stated to be still smaller.

The chief point to bear in remembrance is that the adipose tissue consists of two distinct parts, one a vital organic and secreting part, the other an inorganic and secreted product, which is void of vital principle. The chemical constitution of fat has been investigated by Chevreul, Braconnot, and more recently by M. Raspail. According to the researches of M. Chevreul fat consists essentially of two proximate principles, *stearine* (*στεαρ*, *sebum*, *sapo*,) and *elaine*, (*ελαιον*, *oleum*.) The former is a solid substance, colourless, tasteless, and almost inodorous, soluble in alcohol, and preserving its solidity at a temperature of 176° Fahrenheit. Elaine, on the contrary, though colourless, or at most of a yellow tint, and lighter than water, is fluid at a temperature of from 63° to 65° Fahrenheit, and is greatly more soluble in alcohol. To the presence of stearine in a large proportion, the intra-serous sebaceous fat owes its solidity and firmness; whereas the elasticity and softness of the subcutaneous adipose tissue, and the marrow, depend upon the predominance of elaine.

It is farther important to attend to the elementary composition of fat. Each variety of fat consists of carbon, hydrogen, and oxygen; and a few, as hog's lard, blubber, nut oil, and almond oil, contain a small trace of azote. The proportion of the carbon is greatest and varies in general from 7-10ths to 4-5ths of the whole. The proportion of hydrogen varies from 1-10th to 1-5th. That of oxygen varies from four or five parts in the hundred to 12 and 13. It appears, therefore, that fat and each of its constituent principles are a highly carbonaceous animal substance.

Little doubt can be entertained that animal fat is the result of a process of secretion. But it is no easy matter to determine the mode in which this is effected. Previous to the time of Malpighi it was a very general opinion that the blood exuding from the vessels was converted into adipose matter. This fancy was refuted by Malpighi, who, departing, however, from strict observation, imagined a set of ducts, (*ductus adiposi*) issuing from glands, in which he conceived the fat to be elaborated and prepared. To this fancy he appears to have been led by his study of the lymphatic glands, and inability to comprehend how the process of secretion could be accomplished by arteries only. The doctrine, though embraced by Perrault, Collins, and Hartsoecher, was overthrown by the strong arguments which Ruysch deduced from his injections; and Malpighi afterwards acknowledged its weakness and renounced it. In short, neither the glands nor the ducts of the adipose membrane have ever been seen, unless we admit the testimony of the Members of the Parisian Academy, who state that they saw them in the civet cat, and to this we must oppose the fact that Morgagni, by anatomical evidence, disproved their existence. Winslow, though willing to adopt the notion of Malpighi, admits, nevertheless, that the particular organ, by which the fat is separated from the blood, is unknown. Haller, on the contrary, aware of the permeability of the arteries, and inferring from the phenomena of injections either of watery liquors or melted tallow, their direct communication with the cells of the adipose tissue, and trusting to the testimony of Malpighi, Ruysch, Glisson, and Morgagni, that fat exists in the arterial blood, saw no difficulty in the doctrine of secretion, or rather of a process of separation; and upon much the same grounds is this opinion adopted by Portal. Bichat, again, contends that no fat can be recognized in the arterial blood, and justly adduces the fact, that none can be distinguished in blood drawn from the temporal artery. To the accuracy of this fact I can bear direct testimony, having repeatedly examined with the view of recognizing the buffy coat, and detecting oily particles, blood, which I had drawn from this vessel,—the latter substance invariably without success. In wounds in the human body during life, and living animals, oily particles may be seen floating on the surface of the blood; but these, it may be said, proceed from the division of the adipose vesicles; and hence it has been inferred that the arterial blood contains no adipose or oleaginous matter.

It may be doubted, however, whether facts of this kind are adequate to prove whether adipose or oily matter does not naturally exist in the blood, and both from the experiments of Chevreul, and those of Lecanu and Boudet it appears that small quantities of adipose or puriloid matter may be obtained from this fluid. M. Chevreul, for example, shows that fatty matter may be obtained from the fibrine of arterial blood; and from a series of elaborate and accurate experiments, estimates the quantity of fatty matter in fibrine at from four to five per cent.* Lecanu and Boudet have also recently shown that crystals of pearly-coloured matter having the characters of an adipose substance exist in, and may be obtained in small proportion from the serum of the blood.† These inferences apply, according to the authors, to blood in its healthy state.

In certain states of the system the blood drawn from the veins has presented serum of an opaque or milky appearance, and which has been proved to depend on the presence of adipose or oleaginous matter. Thus, independent of opaque or milky serum noticed by

* Journal de Physiol. tom. iv. p. 119.

† Journal de Pharmacie, 1830-33.

Schenke, Tulpius, Morgagni, and others, Hewson and several cotemporary observers remarked instances of opacity and milkiness of the serum of the blood, and from ocular inspection as well as experiment and observation, inferred that these appearances arose from the presence of oil in the blood or its serum. Soon after Dr. Gregory, in his *Conspectus*, or View of the Institutions of Medicine, was led to infer apparently from the fact stated by Hewson, that in persons in whom the serum was opaque or milky, this depends on the presence of fat which is undergoing absorption, or resumption into the system. This representation, however, was entirely conjectural; and no direct proof of the fact that oil does exist in certain states in the venous blood was given till Dr. Traill, in 1821 and 1823, furnished accurate chemical evidence on the point. The inferences of Dr. Traill have been since confirmed by the experiments of Dr. Christison, who found that milky serum contains oleaginous or adipose matter, consisting of the two adipose principles elaine and stearine.*

The general conclusions, therefore, that may be deduced from the facts now stated are that in the healthy state adipose matter in small proportion exists in the fibrine of the blood, and in a still smaller portion in the serum; and that in certain morbid conditions of the system, in which there is any process of misnutrition or *paratrophia*, oily matter in considerable quantity may be found in the blood, either in consequence of absorption or non-deposition.

To account, however, for the secretion of adipose matter, it is not absolutely requisite to prove that oleaginous or adipose matter exists in the circulating fluid. Even were it ascertained that oil or adipose matter does not exist, or cannot be detected in any of the elements of healthy blood, the fact would not form a stronger argument against its formation from that fluid, than in the case of several other principles which enter into the composition of the animal tissues, and which nevertheless do not exist in the blood. Thus neither gelatine, which exists abundantly in skin, tendon, cartilage, ligament, and bone,—nor osmazome, which is found in muscle, are contained in healthy blood. But we know that the chemical element of these substances exist in the blood, and we farther know that gelatine consists very nearly of the same chemical elements as albumen; and we must infer, therefore, that it is the faculty of the living tissues or vessels to arrange these elements in that manner and proportion in which they may constitute respectively gelatine and osmazome. The same reasoning may be applied to explain the formation of fat in the adipose tissue. Its elements already exist in the blood, and the living agency of the tissue seems all that is requisite to effect its deposition. Its composition and history would also show that it is a secreted product which consists of superfluous chemical elements not required in the formation of the albuminous and gelatinous tissues.

On this subject the interesting experiments of Berard* and Dobereiner† may, perhaps, furnish some intelligible means of illustration. The former chemist found that by mixing one measure of carbonic acid, ten measures of carburetted hydrogen, and twenty of hydrogen, and transmitting the mixture through a red-hot tube, he procured artificially several white crystals which were insoluble in water, soluble in alcohol, and fusible by heat into an oily fluid. The latter chemist prepared a similar substance from a mixture of coal-gas and aqueous vapour.

It may therefore be inferred that while animal fat is chiefly a combination of bicarbonated hydrogen with oxygen, or, in other words, a highly carburetted hydrate of oxygen, and contains either little or no azote, it is the animal substance which makes the nearest approach in chemical constitution to the vegetable principles. So close, indeed, is this approximation that Raspail thinks it may be in this repect compared with starch; and as the different forms of *fecula* are prepared by the vegetable tissues for the nutritious stores of the vegetable during the process of development, he observes that, in like manner, fat is deposited whenever the nutritious function is in excess in the animal organs.

It was a singular fancy of Fourcroy that the deposition of fat in animal bodies was intended as a sort of vent for the superfluous and unnecessary proportion of hydrogen, since the idea is at variance with chemical facts; and it is not less singular that such a hypothesis should receive any countenance from Blumenbach. Carbon is the principle which predominates most largely in fat; and if any attention is to be given to such views, the adipose tissue ought to be regarded as the outlet for superfluous carbonaceous matter, or at least carbonaceous matter in a much larger proportion than hydrogen and oxygen. The proper physiological view, however, of this question appears to be,—that as the tissues of the animal body consist chiefly of carbon, hydrogen, oxygen, and azote united in variable proportions, and as most of these tissues either contain or seem to require azote, the adipose appears to be destined to receive whatever carbon, hydrogen, and oxygen, are not required to be united with the azote, in the formation of the albuminous, the gelatinous, or the albumino-gelatinous tissues.

On the mechanism of the deposition of fat we possess no exact information. But various facts may tend to throw some light on the circumstances under which it takes place, and the history of the state of the adipose tissue at different periods of life is instructive.

In the fœtus the adipose tissue contains a sort of whitish, solid, granular matter, which resembles adipocere rather than genuine fat.

* Edin. Med. and Surg. Journal, vol. xxxiii. p. 274.

* Ann. de Chimie, 1817, t. v. p. 290.

† Zur Pneumatischen Phytochemie, 8vo. Jena. 1822.

Thus it is less oleaginous, and more brittle and friable than true fat. In the infant this layer continues the same in quantity, but a little more oleaginous, till the period at which the individual begins to exert the muscles of locomotion. The fat then rapidly diminishes in quantity, and after the child has begun to walk and run, the fat has almost entirely disappeared from most parts of the adipose tissue, except the orbits, cheeks, neck, buttocks and the flexures of the joints; but even in these regions it is much less abundant and much more consistent.

The marrow presents similar changes. The bones of the fœtus are void of a distinct medullary canal, and present merely a reddish, homogeneous, vascular pulp, somewhat consistent, but presenting soft compressible portions. This state continues some time after birth. As the individual passes from infancy to childhood, the interior of the bone is formed into *cancelli*, adipose or oleaginous matter is deposited in the intra-osseous tissue within the *cancelli*, and as the vessels of the medullary membrane gradually mould the medullary canal, this oleaginous matter is most abundantly deposited in the interior of the cylindrical bones. The marrow, however, is much less oleaginous, and more like a pulpy paste than it is in the adult.

During the periods of boyhood and youth fat continues very sparing in the adipose tissue, and especially in the male sex. After puberty, however, it becomes more abundant, especially in females. After this period the deposition of fat depends more or less on the habits of the individual, as to eating and drinking and corporeal exertion. In general the deposition of fat becomes more copious and general after the age of forty or forty-two than previously.

From these several facts it appears to result that fat is to be regarded as a secretion by the capillary vessels of the adipose tissue from the blood, and that the tissue and its vessels are to be distinguished from the fat or the matter secreted in the relation of vital agents and organic products. Upon the whole the idea of Haller as modified by Mascagni regarding the origin of the fat appears to be the most probable, viz. that, while the arteries secrete an imperfectly formed oily fluid, the thinner parts are absorbed either by lymphatics or by veins, and the residue is left in a more consistent and solid form.

I think, in conclusion, that, taking all the circumstances already stated into consideration, it may be inferred that adipose matter, or its constituent elements exist in the blood, chiefly as complementary elements of the albuminous, gelatinous, osmazomatous, or gelatino-albuminous principles employed in the nutrition of the several tissues; and that, as the carbon, hydrogen, oxygen, and azote are employed in the formation of the latter tissues, the great excess of carbon, and the smaller excess of hydrogen and oxygen, not employed in the formation of these tissues are arranged by the capillaries in such proportions as to form adipose matter; and that this adipose matter, though fluid, when first formed, becomes more consistent and fixed after deposition in its appropriate tissues.

The pathological conditions of the adipose tissue.

1. *Inflammation.*—From various facts, and especially, observing the phenomena of certain cases of what have been denominated *diffuse inflammation* of the cellular membrane, I formerly inferred that the peculiar phenomena of certain intense and malignant forms of this disorder, depend on inflammation not of the cellular membrane, but of the adipose tissue. This conjecture I have since had opportunities of completely verifying as to certain, if not the majority of cases of diffuse inflammation.

a. In cases of diffuse inflammation affecting the arm, the inflammation has spread along the adipose membrane, producing sero-purulent suppuration and sloughs of the adipose tissue. In cases of inflammation at the verge of the *anus*, the disease spreads along in the same manner, and affects, almost exclusively, the adipose tissue around the *anus* and *rectum*, and along the *glutæi* muscles. It is in the same manner that the adipose cushion, with which the bloodvessels are surrounded, is occasionally the seat of a species of bad inflammatory action terminating in fetid and sloughy suppuration.

That these forms of diffuse inflammation truly depend on inflammation of the adipose membrane, I must further maintain, from the fact that the disease occurs not only in the external adipose cushion, but in the internal or sebaceous fat. I have seen an example of inflammation in the adipose cushion surrounding the left kidney, in which the whole of this substance was converted into an ash-coloured, fetid, semifluid pulp, mixed with shreddy filaments, and in which this suppurative sloughing process had opened a passage from the fat of the left kidney into the interior of the transverse arch of the colon. The instance of inflammation and subsequent mortification of the adipose membrane surrounding both kidneys, detailed by Dr. Thomas Turner, in the fourth volume of the Transactions of the College of Physicians in London, is an example of the same species of disease. In the case witnessed by myself, the disease gave rise to the usual symptoms said to attend diffuse inflammation. Though no great degree of pain was felt, the pulse was quick and small, the tongue brown and dry, the countenance dingy and lurid, and the eyes heavy, the bowels difficult to be affected by medicine, the urine scanty and high-coloured, and at length suppressed; and the patient, after muttering delirium and *typhomania* on the second day of the attack, with *subsultus tendinum*, passed into a comatose state, which terminated on the fourth day in death.

b. This doctrine further does not rest upon evidence deduced from the mere symptomatic characters of the disorder. In fatal instances of diffuse inflammation, we find the adipose membrane not only partially mortified and suppurated, but that part of it adjoining to the skin and to the bloodvessels very much loaded, with injected vessels containing dark-coloured blood.

c. It is chiefly in the corpulent, either by habit or by age, that this disease assumes its most exquisite, intense, and unmanageable forms. In persons of this description, who it is matter of common observation are generally not only plethoric but bloated, and liable to imperfect circulation, and disorders of the circulation and secretions generally, and in whom very slight causes often induce serious disorders, the adipose tissue appears to lose a great proportion of the small degree of vital energy which it possesses, and the more abundant its secreted product is, the less active are its vessels and the inherent properties of the membrane. In consequence of this greatly impaired energy, slight causes, as cold, injury, punctures, &c. produce suddenly a complete loss of circulation and action in the tissue; for it is not increased but diminished action; and this impaired energy continues, until the natural functions of the tissue become extinct. It is thus that the secreted or inorganic matter of the adipose tissue becomes, as it were, a cause of strangulation of the tissue itself, or at least leads so directly to suppress the energies of its organic part, that it is incapable of resisting morbific agents of ordinary power, and hence the organic part either may be smitten with immediate death or is very easily made to assume a very low and imperfect form of morbid action, which speedily terminates in death.

On this subject it is further proper to observe that Mr. Bromfield, surgeon to St. George's Hospital, who sixty years ago maintained the distinct characters and situation of the adipose membrane from the cellular, taught also that the former was liable to inflammation, but erroneously imagined that this inflammation was of the circumscribed kind only.*

2. *Hemorrhage.*—Effusion of blood into the adipose tissue is not very common. It is observed in the same circumstances nearly in which it occurs in the filamentous tissue. Thus it has been seen in land and sea-scurvy. Huxham observed it in fevers with petechial eruptions. And Cleghorn states that one of the appearances after death in the continuous and malignant tertians of Minorca was extravasation of blood in the form of black patches in the adipose layer of the mesentery, omentum, and colon.

3. *Excessive deposition.*—In certain subjects, and in peculiar circumstances, the quantity deposited is enormous. The average weight of the human subject at a medium size is about 160 pounds, or between eleven and twelve stones. Yet instances are on record of its attaining, by deposition of fat in the adipose membrane, the extraordinary weight of 510 and 600 pounds, or from thirty-five to forty stones. Cheyne mentions a case in which the weight was 448 pounds, equal to thirty-two stones. In the Philosophical Transactions are recorded two cases of persons so corpulent, that one weighed 480 pounds and another 500 pounds. And the Breslau Collections contain cases in which the human body weighed 580 and 600 pounds.

In females and in eunuchs it is more abundant than in males; in females deprived of the ovaries it is more abundant than in those possessed of these organs; and it is well known that sterility is frequent among the corpulent of both sexes. In some circumstances this accumulation may be so great as to constitute disease, (*polysarcia adiposa* of several nosologists); and in other circumstances the deposition of fat is a means which the secreting system seems to employ to relieve fulness and tension of the vessels, and if not to cure, at least to obviate morbid states of the circulation. (Parry.) Accumulations of fat are said to take place in some animals in a few hours in certain states of the atmosphere. During a fog of twenty-four hours continuance, thrushes, wheat-ears, ortolans, and red-breasts are reported to become so fat that they are unable to fly from the sportsman. (Bichat.)

4. *Extreme diminution.*—The diminution or disappearance of fat is much more frequent than its extraordinary abundance. This diminution is said to depend on one or other of the following causes. 1st. Long abstinence, as in fasting, and the periodical sleep of dormant animals; 2d, organic diseases, as consumption, cancer, disease of the liver, of the heart, ulceration of the intestines, &c.; 3d, purulent collections or secretions; 4th, leucophlegmatic and dropsical states; 5th, gloomy and melancholy thoughts or passions; 6th, long and uninterrupted effort of the intellectual powers; 7th, preternatural increase of the natural evacuations, as in cholera, diarrhœa, diabetes, &c. mucous discharges, especially from the pulmonary and intestinal membranes, as in chronic catarrh, inflammation of the intestines, and dysentery; 8th, long and intense heat, whether natural, as during hot summers, or artificial, as in furnaces, hot-houses, &c.; 9th, running, riding, and every species of fatiguing exercise long-continued, as is exemplied in the case of grooms at Newmarket, Doncaster, &c.; 10th, states of long disease, not organic; 11th, night-watching and want of sleep in general; 12th, immoderate use of spirituous liquors; 13th, habit of eating bitter and spiced or acid aliments.

Yet even in these states the fat of the animal body is seldom entirely wasted. In several organic diseases, in which great emaciation takes place, a considerable quantity of fat is always found in the orbits behind the eyeball, round the substance of the heart, around the kidneys, in the colon, and in the mesentery and omentum. Thus one or both lungs may be extensively occupied by tubercles and indurated portions giving rise to the usual symptoms of pulmonary consumption terminating fatally, yet without removing the fat from the subcutaneous layer of the chest and belly; and in various organic affections of the brain especially, a considerable quantity of fat is found, not only in the subcutaneous layer, but at the outer surface of the serous membranes.

* Chirurgical Observations, vol. i. p. 94.

According to the observations of William Hunter, anasarcous dropsy is the only disease in which the fat of the adipose membrane is entirely consumed. "This disorder, when inveterate, has that effect in such a degree, that we find the heart or mesentery in such subjects as free from fat as in the youngest children." This, however, is in some degree denied by Bichat, who contends that it is not uncommon to find much subcutaneous fat in subjects greatly infiltrated.* It is obvious that much will depend on the stage of the disease. It cannot be expected that the moment serous infiltration appears in the filamentous tissue, all the fat should be at once removed from the adipose. The process of absorption is gradual as is that of deposition; and the inference of Hunter may be regarded as nearly exact in reference to long-continued, or what he terms inveterate dropsy. It is certain, that while it is very difficult to deprive the bones of ordinary subjects of oil, those of dropsical subjects are the only ones which it is possible to obtain free from this substance.

In certain diseases, especially those the termination of which is attended with serous effusion into the cavities of the serous membrane, the fat is partly absorbed or may be converted into a sort of sero-gelatinous fluid. In chronic dysentery, for example, the subcutaneous fat and that of the heart and omentum, in a great measure disappear, while in their place we find effused an orange-yellow coloured sero-albuminous fluid, of a jelly-like aspect, which coagulates on the application of heat or the addition of re-agents. In the bodies of those, also, cut off by scirrhous disorganization or cancerous ulceration, the greater part of the fat is in like manner absorbed, and in its place appears a dirty orange-yellow coloured sero-albuminous fluid.

The removal of the fat from its containing membrane is effected by the process of absorption, the agents of which are supposed by William Hunter, Portal, Bichat, and Mascagni, to be the lymphatics. According to the results of the experiments of Magendie, Mayer, Tiedemann and Gmelin, Segalas and others, it must, in some measure at least, be ascribed to the influence of minute veins. It is a point of some interest to know in what form it is absorbed, whether as oily matter, or after undergoing a process of decomposition The observation of Dr. Traill, above quoted, would lead to the former view; but it is not easy to conceive that this should be uniform. We want, in short, correct facts on the point at issue.

5. *Adipose sarcoma*.—This consists in an unusual deposition of firm fatty matter in cells, the component fibres of which are sufficiently firm to give it consistence. The tumour, which is generally globular, is always surrounded by a thin capsule, formed by the condensation of the contiguous filamentous tissue. The tumour is supplied by a few bloodvessels, which proceed from the capsule, but which form so slender an attachment that they are readily broken, and the tumour is easily scooped from its seat. This sort of tumour occurs almost invariably in the adipose membrane, and seems to consist in a local hypertrophy of the part in which it is found. It may have a broad basis, but is often pendulous, or attached by a narrow neck or stalk. It is the most common form of sarcomatous tumour, and may occur in any part of the body in which there is adipose membrane, but is chiefly found on the front and back of the trunk, and not unfrequently on two places at the same time.

6. *Steatoma*.—In adipose sarcoma the adipose matter is deposited in cells, and the tumour derives a degree of firmness from the fibres with which it is thus traversed in every direction. In other instances, however, the adipose matter is deposited in a mass in the cavity of a spherical or spheroidal cyst, formed in the filamentous or adipose tissue; and the tumour is soft and compressible, and seems to contain fluid or semifluid matter. When cut open it is found to contain a soft semifluid matter of the consistence of honey, but of oily or adipose properties. In such circumstances the inner surface of the cyst, or at least the vessels of this surface, are the agents which secrete the fatty matter. This tumour may occur either in the filamentous or the adipose tissue, but is to be regarded as an example of local deposition of adipose matter. It may appear in any region of the filamentous tissue, but is most frequent about that of the head and face. Small steatoms are not unfrequent in the eyelids and in the scalp. Larger ones are more frequent about the neck.

7. *Lipoma*.—This name was first applied by Littré to a wen or cyst, filled with soft matter, possessing the usual properties of animal fat. The matter of steatom, according to this surgeon, is either not or imperfectly inflammable, by reason of its degeneration or commixture with some other animal secretion. The propriety of this distinction has been denied by Louis and others, who maintain that these tumours differ in nothing, unless perhaps in degree. It has been favoured, nevertheless, by Morgagni, and adopted by Plenck, Desault, Bichat, and various foreign surgeons, and is defended by Boyer, who represents the steatom as differing from *lipoma* in the matter being white, firm, and changed from its original character, and in possessing the tendency to degenerate into cancer. Plenck had previously distinguished the *lipoma* by its being destitute of a cyst, a circumstance not required by Littré.

Though thus admitted to differ, the anatomical character, as given by Morgagni, and confirmed by Boyer, is in both nearly the same: a cyst, containing unchanged fat, or granular adipose matter, in cells formed by the original fibres of the adipose membrane, according to Morgagni, or those of the filamentous tissue, according to Boyer. At the base or stalk, in the case of pendulous steatom, the cells are compressed, but loose in the body of the tumour.

This description, with the alleged cancerous

* Anat. Gén. vol. i. p. 57.

tendency, accords more with the characters of the adipose *sarcoma* than those of the genuine wen. Personal examination enables me to say, that, in the case of small steatoms of the scalp, eyelids, face, &c. no fibres of this kind are recognized; and to such, if any distinction be adopted, the name of *lipoma* should be confined. In the case of such larger steatoms as I have seen in other regions of the body, though the contents are firmly connected together, and some filamentous threads may be seen here and there, or the tumour may even be separable into masses, I have not been able to trace the distinct arrangement of cells, mentioned by Morgagni and Boyer. Weidmann mentions, that in one case the matter of steatom was a sort of liquefied fat, and in another firm and dense, and not divided into lobes or cells. The other forms of encysted tumours, distinguished by the names of *atheroma*, (*αθηρωμα*, *pulticula*, *ab αθαρα*, *pullis genus*,) and *meliceris* (*μελικηρις*, *mel* and *cera*, honey wax,) are to be viewed rather as varieties of the steatom than as generically different. The substance contained may differ in consistence, but is nearly the same in essential qualities.

8. *Melanosis.*—The adipose membrane is a frequent seat of this singular deposition. The black or melanose matter is found in the subcutaneous adipose membrane, and the subjacent cellular tissue of the chest and belly; it is not uncommon in the fat of the orbit; it is very commonly seen in the adipose cushion on the forepart of the vertebral column, on that surrounding the kidneys, and in the fat of the *anus* and *rectum*; it is found in the anterior and posterior mediastinum; and it is found between the folds of the mesentery, of the mesocolon, and of the omentum. It is also found in the substance of the marrow of bones; and, perhaps, in most cases in which the osseous system appears to be stained with the melanose deposite, the dark matter may be traced to the medullary particles, the situation of which it is found accurately to occupy.

In all these situations it appears in various degrees of perfection, and in different forms. It may be disseminated in black or inky spots, through the adipose membrane; it may be accumulated in spherical or spheroidal masses of various size and shape; or it may be found in the form of brown or ebon-coloured fluid or semifluid, enclosed in a cyst formed of the contiguous tissue, more or less condensed.

The melanose matter is entirely destitute of organization, and is to be regarded as the result of a peculiar secretion. No vessels have been traced into it; and when bodies affected with this deposite are minutely injected, the vessels can be traced no farther than the enveloping cyst. (Breschet.) It is also to be noticed that it is never deposited exactly in the site of organic fibres, but always between them, and very generally in the precise situation of the adipose particles. These several circumstances show that the melanose disease consists not in a degeneration or conversion into another substance, but in the deposition of a new form of matter in the manner of a secretion.

In what form the melanose substance is first deposited we have few accurate facts to enable us to form a judgment. Laennec is of opinion that it is first deposited in a solid form, and afterwards becomes fluid. The former he considers the stage of crudity, the latter that of softening (ramollisement.) Several facts, however, would lead to the conclusion, that when first deposited it was fluid, and afterwards acquired consistence. Thus in several dissections performed by Drs. Cullen and Carswell,* the matter of the small tumours, which are supposed to be of short duration, were found to be softest, and sometimes as fluid as cream. In like manner, in a case recorded by M. Chomel, in which the disease was found in the liver in the shape of large cysts, the melanose matter was more fluid in the centre than in the circumference of the cysts. Upon the whole, if the melanose deposite be, as is supposed, an inorganic secretion, the idea of its being poured forth from the vessels at first in a fluid or semifluid state is most probable, and most consistent with the usual phenomena and laws of animal processes.

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(David Craigie.)

AGE.—(Lat. *ætas*. Gr. *ἡλικια*. Germ. *Alter*. Fr. *age*. Ital. *età*.) This word, in its most extended sense, may express any period of duration. In reference to the human body it is used to denote either the whole time occupied by this system in passing through its several stages from birth to decay, or, in a more limited signification, that particular portion of existence commonly designated old age. It is in the former of these meanings that we employ the prefix to the following article; in other words, we propose to give an account of the organic and functional changes which the human system undergoes, from the commencement of extra-uterine life to the period of its dissolution by natural decay.

The term of human existence has been variously divided, and in many instances with a view to adapt its divisions to certain fanciful notions respecting the power of num-

* Trans. Med. Chir. Soc. Edinb. vol. i. p. 264.

bers; but the only rational principle on which we can distinguish certain definite periods, must be that of observing alterations in the condition of the whole body or of its several organs, and the correspondence which they bear to particular epochs. The old Aristotelian division of human life into three stages, growth, maturity, and decline, is founded on this principle; for, viewing man as a whole, the conditions in which he is an imperfect, a complete, or a declining member of his species, are well marked. But these conditions are capable of subdivision according to the changes which particular organs have undergone; in other words, man, in the progress of his *perfectionnement*, makes certain acquisitions in his structures and functions, and in his decline suffers certain losses and impairments; the more striking of these additions to, or subtractions from his resources, suggest the well-known division of existence into infancy, boyhood, puberty or adolescence, manhood, old age, and decrepitude. It is not our intention to discuss the subject of age by describing the characteristics of the stages last enumerated; we think it better to take a view of the general revolutions which transpire in the human economy during growth, maturity, and decline, and under each of these heads to mention the changes which particular organs undergo in the course of time, without limiting ourselves to distinct stages, the determination of which must be, to a certain extent, arbitrary.

The consideration of the alterations which take place in the body during its progress from infancy to manhood might very properly be preceded by some remarks on those ultimate processes which are essential to growth, viz.—nutrition, secretion and absorption; but, for information upon this interesting subject, the limits prescribed to this article compel us to refer the reader to that upon NUTRITION, in which the processes alluded to will be viewed in relation not only to the development, but also to the maintenance, and to the decay of the tissues.

On comparing a young with an adult animal we are at first struck by the difference in bulk; but immediately afterwards our attention is attracted by the difference in their respective capabilities of action,—a difference not merely proportionate to that of size. A closer examination informs us, that in the infant many of the parts of the body are absolutely incomplete, as organs or instruments, and we proceed to investigate whether this imperfection holds with all the organs or only with some of them; and if the latter be the case, whether the parts thus existing only in a rudimentary state belong to a particular class. Now, the organs and functions of man, in common with those of other animals, are divided into those which he shares with organic beings in general, and those which distinguish him as an animal; the former subserving his own independent existence, the latter his existence in relation to external objects of his consciousness; these more or less subjected to the control of volition, those removed, under ordinary circumstances, from the government of this principle. Hence these two classes have been variously named organic and animal, nutritive and relative, automatic and voluntary; and, as life is a term employed to designate the collective functions according to some physiologists, or the cause of them according to others, we have organic life and animal life, &c., &c. But the animal functions are truly supplemental; they could not subsist but by virtue of the organic; while, on the other hand, the latter are perfectly capable of a separate existence, as in the vegetable world, or in those conditions of animal life in which its characteristics are all but suspended, such as profound sleep and apoplexy. Yet, although the functions of relation are thus dependent on those of nutrition, it is evident, at a moment's glance, that the latter viewed collectively in an animal structure, would present an aspect altogether incomplete, and different from that which we notice in the system of a vegetable. In the one case they were obviously intended to act only for themselves and for one another; in the other they have an ulterior object to fulfil, but for which they would not have been called into existence and operation; this object is the production and support of the functions that constitute the animal. If we now look at the new-born infant in contrast with the full-grown man, we at once perceive that the essential difference between them has reference to the life of relations; in other words, the immaturity of the former is not determined by the state of the vegetative organs, which, as organs, are perfect, but by the undeveloped conditions of the parts which are to receive impressions from, and to re-act upon surrounding objects. Thus, on the one hand, we observe that the food adapted to the little being is rapidly converted into chyle, that the blood, after undergoing its requisite changes, performs its circuit freely and effectively, and that the activity of the nutritive, secernent, and absorbent processes is evidenced by the quick increase of growth, and by the abundant fluids contained in the various tissues. But, on turning to the relative functions, we find the case altogether reversed; sensation is dull, faint, and flitting; voluntary motion scarcely exceeds the amount necessary for obtaining nutriment from the parent; while the demonstrations of intelligence are the very lowest compatible with our belief in the possession of such a principle by the being in question. An examination of the organs devoted to these several actions leads to results in accordance with what we observe in the functions themselves; in the one class the organization is complete, in the other much remains to be accomplished. If the apparatus of digestion be inspected, the parts employed in deglutition, viz., the tongue, pharynx, and œsophagus, will be found fully formed; in the stomach the parts required for accommodating the aliment during its stay and for mixing certain fluids with it, are properly developed; no deficiency is observable in the structure of the liver and pancreas; and the chyliferous vessels are pervious, extensile, and perhaps contractile. If we proceed to the organs of circulation, similar conditions are observable. In the heart the several cavities, valves, and fibrous arrangements are duly proportionate to each other, and possess such qualities of firmness, pliancy, distensibility and contractility as are required for receiving, expelling, agitating, and keeping in separate compartments the two different kinds of blood; the arteries are found resistent enough to hold the blood within their calibres, and at the same time elastic enough to adapt themselves to the varying quantity of their contents, while the veins are found so organized both as to the muscularity of their coats, and to the perfection of their valves, as to be quite capable of conveying the fluid back to the heart. Not less complete is the apparatus of respiration, whether we regard the development of the diaphragm, or the elasticity of the thorax, or the cellular and tubular arrangements in the lungs and their appendages. For affording the necessary conditions for the occurrence of those molecular motions which constitute deposition and absorption, and upon which secretion also depends, we find an infinite number of capillary tubes well formed for supplying the fluids from which new particles may be taken, and to which old ones may return, and so disposed as not to interfere with the action of any supposable chemical affinities. If we next direct our attention to the organs of the animal functions, an opposite set of facts will directly meet us. In the locomotive system, the bones are discovered imperfectly ossified, the muscles deficient in fibrin, and the tendons and ligaments in firmness and density. Of the organs of sensation it may be said, in general terms, that the mechanism employed in the application of the appropriate stimulus is, for the most part, incomplete, while a difference is also observable in certain properties of the nervous substance.

From this view it might at first be concluded that, in order to trace the changes that ensue between the commencement of extra-uterine life and the attainment of maturity, we have only to look for them in the organs of the relative life. But the survey that we are about to take of the changes in question will show that the other class of organs are by no means exempt from alteration, although the changes are not those of development. They will be found to have reference to *degree* or *amount* of function rather than to capacity.

The external characters of the infant just eliminated from the uterus at the full period of gestation are as follows:—the integuments are thin, tender, and covered with a white unctuous matter; the nails just reach the ends of the fingers; the trunk and limbs are round and plump; and the articulations are in a state of flexion. The average weight of the body is about six or seven pounds; the length varies from seventeen to twenty-one inches, sometimes falling short of or exceeding these limits. The point which lies midway between the two extremities is at the umbilicus. The dimensions of the head and of the abdomen are very large in proportion to the other cavities, and as compared with their own measurements in after periods of life. The pelvis looks contracted, the thorax flattened at its sides and prominent in front, and the lower extremities are less developed than the upper. A line drawn from the occiput to the chin measures five inches and three lines; from the occiput to the forehead four inches and three lines; and from the vertex to the base of the skull three inches and six lines. The circumference of the head, taken along the course of the median line, is from thirteen to fourteen inches; but taken horizontally, and passing over the parietal protuberances, it seldom measures more than ten or eleven inches. The contrast between this general aspect and that of a full-grown man is too obvious to require any representation of it here.

The characters of the interior will be best described and understood by examining analytically the several apparatuses of the functions. Of the latter the most simple and primitive is assimilation, consisting of certain molecular motions which maintain, repair, and mould the organic tissues. We have already observed that the requisites for this function are perfect in the new-born infant; a copious supply of the fluid from which the textural particles are to be elaborated, a ready ingress for this fluid, and a no less ready egress for that which receives the particles no longer required in the process. All that we know of the mechanism employed is a porous extensile substance, varying in its chemical constitution according to the nature of the tissue. Porosity is resolvable into a collection of infinitely minute tubes, and the degree of porosity is, therefore, determined by the number of the tubes; the extensibility depends on the composition of the tubes. The tissues of the infant are soft, they abound in fluids, and are more capable of imbibition or artificial injection than at later periods of life; this being consequently possesses a complete mechanism of nutrition. But this mechanism can be of little utility unless the nutrient fluid be supplied liberally, and after furnishing the atoms for the formation of the several textures give place to fresh supplies. These conditions are afforded by the arteries and veins.

There is no period of human existence in which the processes of interstitial growth are so active as in infancy, whether they be instanced in the accretion of matter, in the change of composition, or in the modification of form. This fact is in harmony with the state of the capillary system just described, and it will be found to correspond no less with the relative construction of the arteries and veins. The function of the former of these is to convey the blood into the tissue, of the latter to take it away; consequently in a part where the growth is most energetic, we might, *à priori*, expect that the former would be more numerous, capacious, and distensible. This is well known to be the case from actual observation, partly of the effects of artificial injection, and partly of the phenomena of disease. An examination of the textural properties of the two sets of vessels leads to the same conclusion. Sir Clifton Wintringham, in his Experimental Enquiry, fully demonstrated that the venous coats in the young animal far exceed the arterial in density, and that, consequently, they are less subject to distension. When maturity is attained, the disproportion between the résistances of these vessels no longer exists.

However well provided the infant may be with the mechanical apparatus of pores and vessels, these can be of no avail unless the fluid they contain possesses certain chemical properties. Now the blood in early extra-uterine life presents the same general characters as in more advanced periods; but there is yet wanting a comparative analysis of this fluid at different ages.* Inferentially we can entertain no doubt that it is fully adapted to the purposes of nutrition, when we consider the conditions of the chylifactive and respiratory functions, and that, although the differences of its composition in early and in more mature periods have not been defined by experiment, they must bear a relation to the different degrees of nutrition and secretion. The difference, however, between the blood of the infant and that of the aged is perceptible to the senses, and will be noticed hereafter.

Pursuing the channels of the blood to the heart, we find this organ, as stated above, complete in its functions. Its volume, however, is large in proportion to the size of the body. Its parietes are less firm in texture, and of a paler colour than they afterwards become; but their contractility is more active. The pulsations are from 120 to 140 in a minute. The large volume is in harmony with the quantity of the fluid, the comparative weakness of its parietes with the small extent to which their impulse requires to be propagated, and with the trifling resistance; and the quick successions of its contractions furnish the fresh supplies of the nutriment required by the energy of growth. In the progressive development of this organ we notice that the bulk, although increasing so long as general growth continues, is proportionately smaller, a circumstance that corresponds with the diminution of the circulating fluid; the fibres become stronger and of a deeper hue, so that the contractions are more capable of propelling the blood through the greater extent which it has now to traverse, or, more strictly speaking, of communicating a shock to a greater column; but the pulsations are slower, agreeably to the diminished requirements on the part of the capillary actions. We must not omit to observe that at birth the parietes of the left ventricle scarcely exceed those of the right in thickness; but from this period an alteration commences, and rapidly proceeds until the thickness of the latter is to that of the former as 1 : 4. This change corresponds with the closure of the foramen ovale, the obliteration of the ductus arteriosus, and the consequent execution of the systemic circulation by the left ventricle only. The relative capacities of the right and left cavities begin to alter soon after birth. From tables given by Meckel it appears that, while at birth the capacity of the former compared with that of the latter is as 1 : 1¼, at the age of 50 it is nearly 3 : 1.*

The lungs at the moment of birth undergo a more remarkable alteration in their form, their texture, and their contents, than any other organ in the system; but during infancy and childhood they present no appreciable change in their organization, although a change must be inferred from the increase of their function. In infancy there is a smaller consumption of oxygen; and the power of generating heat, a function so intimately connected with respiration, is inferior to that possessed in later periods. Much light has been thrown on this subject by the researches of Dr. Edwards; and practical observations of the highest importance in the management of infants, founded upon the facts which he has ascertained, are to be met with in his valuable work.† The inspirations and expirations are more frequent at this early period, although the chemical actions between the air and the blood are less considerable. This greater frequency is a necessary accommodation to the rapidity of the circulation. At puberty there is a marked development of the organs of respiration; the volume of the lungs increases in conformity with the expansion of the thorax; while the greater determination of the blood to their vessels is indicated by the deeper hue of the parenchyma, by the liability to pulmonary hemorrhage, so characteristic of this period, and perhaps also by certain diseases which affect the nutrition of these organs. The corresponding activity of function is indicated by the increased power of calorification, the energy of muscular motion, and the exaltation of the cerebral actions; functions well known to have a direct relation with that of respiration; while the establishment of the generative faculty appears to own a connexion, though somewhat more remote, with the pulmonary development.

We pass from the system which imparts new properties to the blood to that which supplies it with nutriment. No imperfection is discoverable in the apparatus of digestion in the new-born infant; every organ is complete as an organ, but passes through various changes in adaptation on the one hand to the food that is supplied, and to the mode of receiving it, and on the other hand to the demands of the other parts of the body. The organs employed in conveying and modifying the chyle, viz. the lacteals and the mesenteric

* De Blainville states, on the authority of Fourcroy, that in infancy the albumen of the blood is more abundant, that the fibrin is softer and more gelatinous, and that the phosphates are in smaller proportion than in succeeding periods. Cours de Physiologie, t. ii. p. 262.

* Manuel d'Anat. t. ii. p. 284.

† On the Influence of Physical Agents, &c. translated by Drs. Hodgkin and Fisher.

glands, are in a state of high development, as indicated both by their size and by their tendency to disease. The stomach and duodenum are fully formed, but the sensibility of their mucous membrane is adapted only to the milk of the mother; any other kind of food has a greater or less tendency to produce irritation. This membrane is thick, extremely villous and vascular, and consequently of a rose-colour.* In young persons it assumes a milky or satin-like appearance; in the adult it becomes slightly ash-coloured, especially in the duodenum and in the commencement of the ileum; in the old subject it is more decidedly ashy. Its whitish appearance, according to Andral,† is found either in very old persons or in younger subjects who have died of marasmus. In the adult the small intestines, according to Orfila,‡ bear a proportion of eight to one as compared with the distance from the mouth to the anus; in the infant the proportion is no less than twelve to one.§ The large intestines are longer with respect to the small intestines in the infant than in the adult; but their calibre is proportionally smaller. Ascending to the mouth we might be tempted to say that there is evidence of incompleteness in the absence of teeth; but a moment's consideration assures us that the organs collected in this part are all eminently adapted to their function. The food is already prepared by the mother, and only needs to be extracted and conveyed into the pharynx; actions which are perfectly achieved by the lips, cheeks, and tongue. When the period has arrived at which this food can no longer be furnished with safety to the mother, and when all the purposes are accomplished which were intended in this close connexion between the two beings—purposes in all probability of a moral as well as a physical character—the infant is prepared for a more independent existence by the emergence of teeth. This event generally begins about the sixth or seventh month by the appearance of the two middle incisors in the lower jaw; these are followed by the corresponding teeth in the upper jaw; next are seen the lateral incisors below and above: the rest appear in the following order;—the first molars, the canines, and the second molars; those of the lower jaw having generally the priority of emergence. The milk-teeth, as they are called, by the end of the seventh year have given way to the second and permanent series. For the different characters of the two sets, the order of their appearance, and other particulars, we beg to refer the reader to the article Teeth. That the first series should be only temporary is a necessary provision, in conformity with the change in the conformation of the maxillary bones which ensues at the same time.

We must not leave the alimentary tract without observing that the fibres of the stomach and intestines in infancy and childhood are, like those of the heart and other involuntary muscles, more irritable than in after life; hence the contents of these viscera are propelled more rapidly, and the evacuations are more frequent; their tissue is also softer, and their colour more approaching to white.

The liver undergoes a great change after birth both in form and in function. The peculiar circulation of which it formed so important an organ during fœtal life being abolished, the left lobe which nearly equalled the right in volume, is diminished to a third of its original size. But while the umbilical vein and the canalis venosus are obliterated, the vena portæ is developed, and the bilious secretion becomes the predominant function. Of the further changes which this organ experiences, we have very little knowledge, except that the whole bulk is greatly lessened, and that the colour of its parenchyma becomes darker, and that it is more subject to disease in after periods. Occasionally we meet with instances in which the fœtal proportions of the liver continue through life (Andral). The bile has not been carefully examined with reference to particular ages, but it is known to be less viscid and to contain a smaller quantity of its peculiar principles in infancy; while its greater liability to concretions at more advanced periods indicates an alteration in its composition. The gall-bladder, though small at birth, contains bile, green in colour and bitter in taste, and soon becomes enlarged.

The spleen also increases in volume, but what alteration takes place in the progress to maturity, in its function, must, of course, be doubtful until the function itself be better understood. Probably its enlargement is connected with the distended condition of the venous system. Of the changes in the pancreas and salivary glands, we know little more than that their texture increases in firmness. The lacteals, lymphatics, and their respective ganglions have a very marked development. It is to be regretted that no observations have as yet been made upon the composition of the chyle at different ages. There are doubtless many alterations corresponding to the varying activity of the digestive function, and to the kinds of aliment used at those periods.

So much for the organs and functions which are concerned in augmenting or modifying the nutrient matter. Before proceeding to those of the relative life, we must allude to the organs of excretion. The kidneys at birth have not lost the traces of their lobular formation, but these are soon effaced. The weight of these organs at birth is to that of the whole body as 1·80; in the adult 1·240. The medullary portion is more abundant than the cortical in early life. The supra-renal capsules soon begin to shrink from their fœtal size. The ureters are large, and the bladder has a more elongated form than in after periods; it also occupies a higher situation above the pelvis. The functional qualities of these forms are not so well ascertained as the analogy of their organization to

* Billard, Traité des Maladies des Enfans, &c.

† Précis d'Anat. Pathol.

‡ Leçons de Méd. Lég. t. i. p. 62.

§ This statement is at variance with that of Meckel, who says that the small intestine is much shorter in the early periods. Op. cit. t. iii. p. 424.

that of inferior animals. The urine is retained a shorter time in the bladder; it is more aqueous and less impregnated with saline and animal ingredients than in after life; there is also a particular deficiency of urea. Of the intestines we have already spoken; their contents are copious but less feculent than they afterwards become. The perspiration affords a similar character to that of the other excrementitious secretions, being more aqueous, less saline, and less odorous. On the whole it may be said that less activity is indicated in the *egestive* than in the *ingestive* system.

Of the defensive organs, or those which are exposed to surrounding agents, we may remark, in general terms, that although fully adequate to the demands of the infant under the circumstances of his existence, they acquire a development proportionate to his growing independence of the care of others. The skin increases in firmness, and the epidermis in thickness; the sebaceous follicles become larger and more numerous, and the hair is more abundant.

There is a portion of the nervous system which we have every reason to consider more related with the functions which have been just reviewed, than with those of the animal life, and which might *à priori* be expected to bear a corresponding ratio of developement. We allude to the ganglions; they appear to be fully formed at birth, but what changes they undergo between that period and maturity we do not profess to know. In old age their tissue is found hardened, shrunken, and of a greyish colour. (Bichat.)

The changes that we have next to take notice of are of a totally different character from the foregoing. They consist not merely in augmentations of size, correspondently with the general increment of the body, or in modifications of organs according to the altered circumstances under which they have to act, but in processes essential to the completeness of certain organs. These are the parts employed in locomotion, voice, sensation, and thought. We shall begin with the osseous system.

Bones are not subservient to locomotion only; they have, in some parts of the body, the important office of enclosing and defending from external injury the more delicate organs of the system. We shall find, therefore, that in the young animal, according as they fulfil the one office or the other, their development will differ. But whatever be the functions of the bones, they require, for the perfection of that function, three mechanical properties,—firmness, lightness, and tenacity. They must not admit of flexion, and, at the same time, the density of their substance must not render them cumbrous by weight, or brittle in texture. To present these three conditions, the organs in question consist of two principal ingredients, an animal matter and an earthy matter, most intimately interwoven; the one preventing such vibrations as would occasion risks of fracture, the other affording the necessary strength in supporting weights, and in resisting the divellent tendencies of antagonist muscles. The proportion which these parts bear to each other varies with the ages of the human subject. Viewed as a part of the system devoted to the life of relations, bones are used as pillars of support, as levers in various attitudes and motions, and as *points d'appui* to the muscles and tendons. On examining the constitution of these portions of the osseous system in the new-born infant, we find the quantity of calcareous salts comparatively small, and even the animal substance softer than in later periods, in consequence of the greater ratio of gelatine. In growth these proportions undergo a gradual alteration; the gelatine is diminished, the cartilage becomes firmer, and both give way to the deposition of earthy particles: in the increase of density produced by this deposition consists the process of ossification. To particularize the incompleteness of the osseous system would require us to enter upon the anatomy of almost every bone in the body, an investigation incompatible with the limits of this article. Some idea of it may be obtained from the fact that all the epiphyses of the long bones, and the greater number of the apophyses are as yet but cartilaginous; they derive their ossification, not from an extension of the process in the bones to which they are attached, but from ossific centres within their own spheres. In the tarsus the only bones in which ossification has commenced are the astragalus and os calcis. The carpus is entirely cartilaginous. The os innominatum of the pelvis consists of three separate bones; ossification has but just commenced in the descending ramus of the pubis, and the ascending part of the ischium; and the consolidation of the pelvis is not complete till after the thirteenth year. The long bones have no central medullary cavity in the early periods of intra-uterine life; but in the fœtus at its full term, the animal matter which occupied that space has begun to be absorbed, and the deposition of osseous matter takes place in the form of a cylindrical sheath, so that the canal exists at this period, though in an incomplete state. The medullary canal is analogous to the cells of the short and flat bones, and of the extremities of the long bones, which are also incomplete in infancy. The shape of the cylindrical bones is manifestly different from that which they afterwards assume; thus there is a much smaller disproportion between the diameters of the extremities and that of the shaft; the surface is less furrowed by sinuses or roughened by ridges; differences exactly corresponding to the imperfeet development of the muscles, which, when more bulky in their middle portions, require a larger space for their accommodation about the body of the bone, and when stronger in contraction, require attachments that will match them in firmness. The osseous system is not complete till after the age of twenty.

There is no part of the skeleton in which we have a more striking illustration of its gradual development than in the bones of the face and in the cranium. It is not till the seventh year that a separation begins to take place between the tables of the skull, that the frontal sinus begins to open, that the nasal bones lengthen, that the cells of the malar and upper maxillary bones are enlarged, that in consequence of this expansion of their cavities the outer lamina projects, and that the lower jaw is elongated. The stationary condition of the tabula vitrea is conformable to the arrest in the increment of the brain; the extension of the outer table to the increasing power and action of the muscles attached to it; the development of the sinuses and cells to that of the voice and certain of the senses; and the projection of the jaws to the increased number of the teeth. But although these changes commence as early as the seventh year, they are not complete till the twenty-first, or even later. At this time the countenance becomes settled, not merely by the full development of the muscles, which express the predominant emotions of the individual, but also by the complete adjustment of the bony arrangements just enumerated.

Those portions of the osseous system which are employed in protecting the organs enclosed by them from external compression or injury, have attained a degree of growth far surpassing that of the bones devoted to locomotion and to the mechanism of sensation. The ribs, for instance, defending the lungs and the heart, and playing so important a part in respiration, are farther advanced in the ossific process than the bones of the extremities. But the most striking fact of this kind is presented in the spinal column. The annular portions of the vertebræ which form the canal of the medulla spinalis, are found strongly ossified at birth, but the bodies of these bones, which are to be used hereafter in supporting the weight of the head and trunk, are very slightly expanded, and all but devoid of earthy particles, while the processes to which the muscles employed in the flexion and extension of the column afterwards contract attachments, are either only shaped in cartilage, or may be said to have no existence.

Passing from the bones to the muscles, we observe the latter no less incomplete in infancy as it regards their physical characters; they are pale, flabby, and easily torn; they contain less fibrine than in after years; their contractility is weak though easily excited; and the fasciculi and fibres are but loosely connected from the want of the fasciæ and aponeuroses which brace them in later periods. As life advances, the fibres become redder, more distinct, and stronger. A readiness to contract is manifested very early, but it is not till maturity that these organs are able to maintain contraction for any length of time. They suffice well for the quick and buoyant motions of the lively child, but fail in those violent and prolonged exertions required by the labours of manhood. The form of the muscles changes materially in the progress of years; thus, they swell out in the middle, and occasion a great difference in the proportions of the limbs. Those portions of the locomotive apparatus attached to the muscles and articulations, viz. the tendons and ligaments, undergo corresponding changes. In infancy they are soft and gelatinous; gradually they become firmer, their gelatine acquires a more glutinous character, and the membrane which envelopes them is more condensed. Every one knows the different products obtained by boiling the tendinous parts of young and adult animals; in the one they have the qualities of jelly, in the other of glue. The readiness with which the joints of a child are strained or dislocated is likewise well known. The immature condition of the infant is strongly marked in the ankles, which are turned inwards, and would never suggest the use to which the feet are to be applied, but for our familiarity with the change that afterwards occurs. The cartilages and fibro-cartilages are subjected to a development corresponding to that of the fibrous tissue.

Into the composition of the vocal apparatus we know that muscular, fibrous, and cartilaginous tissues enter; and, as these are altered by age, the mechanism which they constitute might *à priori* be expected to suffer similar modifications. The larynx of the infant is small and almost circular; consequently the lips of the glottis and the superior ligaments are very short. This configuration, viewed in connection with the immaturity of the muscular tissue, accounts for the shrill wailing cry, which is the only vocal sound produced at this early period of human existence, and the only one required, since the quick instinct of maternal affection can interpret these simple notes into an eloquent language. No very appreciable alteration takes place in these parts at the time when speech is acquired, for this attainment has more connection with the development and command of the muscles of the pharynx and mouth, as well as with the organ of intelligence, which enables the human being to discriminate sounds and to imitate them. Fortunately the oral and pharyngeal muscles are some of the foremost in development, being required in suction and deglutition. A progressive change goes on in the larynx, though it is not very evident till the period of puberty in the male, when the thyroid cartilage is elongated, and with it the thyro-arytenoid muscle. At this epoch occurs the moulting of the voice, or an accession of gravity in the tones, occasioned by the elongation of the parts just mentioned. The projection of the pomum Adami takes place at the same time. In the female larynx scarcely any change occurs, and the voice in consequence remains acute. We have already spoken of the facial bones and their cavities, parts which exercise a very decided influence on the sonorousness of the voice.

We must now hasten to the consideration of the parts employed in that other distinguishing function of animals, viz., sensation. There are two grand divisions of the organs of sensation, those which we understand, and those which we do not. The former consist of the various kinds of animal mechanism whereby the external causes of sensation are modified, the latter of the nervous substance intermediate to the external excitant, and that state of consciousness which we denominate sensation. We know that the eye collects rays of light and concentrates them on its internal surface, but are utterly ignorant of the changes which the retina, the optic nerve, and the brain undergo in producing that condition of our sentient existence which we call vision. It is true that we are aware that certain states of these parts are incompatible with sight; but why they are so is quite beyond our knowledge. We are, as it regards our acquaintance with the adaptation of nervous tissue to the production of sensation, in the same predicament as a man who watches the working of a steam-engine, and knows that a certain quantity of fuel, of water, of valvular compression, &c. is necessary to its motion, but has no idea of the laws of caloric, vaporization, constitution of elastic fluids, &c. Our science demonstrates the fitness of the external and internal ear for receiving, propagating, multiplying, and diffusing vibrations, but why the contact with the auditory nerve produces sound, is an all but impossible inquiry; as well as the reason why the sensation may be absent when the organ is in perfect order, and the nerve to all appearance unchanged; or why the sensation may occur without vibrations, as in dreaming, and many nervous disorders. The same may be said of the skin; it is well adapted for coming in contact with the points or superficies of bodies, but who can say why the nerves spread over it occasion certain feelings? These remarks are premised merely to shew that it must not excite surprise, if we are unable to point out completely the changes which age produces in the human body, correspondently with the changes of its sentient faculties.

It has already, in all probability, struck the mind of the reader, that the great development of the cerebral system in the infant is inconsistent with the principle which we have been endeavouring to demonstrate, viz., that the growth of the human body consists essentially in the elevation of the organs, subservient to the animal functions, from a rudimentary state. The more we grow, the smaller is the proportion of the brain to the rest of the fabric. But it is no less true that the *functions* of the brain grow with our growth. How then are we to reconcile these opposite facts? We must certainly discard the opinion, that the bulk of the organ is proportionate to its power, and examine the composition and the relations of its various parts to each other.

Limited as our knowledge is of the requisite conditions of nervous substance for its function, we are notwithstanding aware of two extremes of softness and hardness, which comprise those states of the tissue which are compatible with the exercise of its peculiar faculty. Pathologists well know that ramollissement and induration of the brain may produce the same lesion of function, viz., abolition of sensation; while it is equally well known that approximations to the same conditions will produce impairment of this faculty. Now in infancy the brain is extremely soft, almost pultaceous, while in old age it is extremely hard in comparison, and the similarity of the two ages in many respects, but particularly as it regards the functions of the nervous system, is matter of universal observation. It might then *à priori* be suspected that one of the changes in cerebral growth would be a tendency to a certain intermediate degree of consistence, and this is found actually to be the case.

From a careful comparison of the size and weight of the brain at different ages, it was ascertained by the Wenzels, and is demonstrated in tables contained in their work, De Penitiori Cerebri Structurâ,* that although the organ increases very sligthly in bulk after the third year, its weight does not attain its maximum till after the seventh, so that up to this time there is a progressive increase of density. After the seventh year there is no great difference either in size or density. (The size of the brain must not be confounded with that of the head, which after the period that we speak of, is determined by the growth of the external table of the skull, correspondently with the projection of the bones of the face.) There must, therefore, be some other change than that of density, to account for the augmentation of intellectual power in the succeeding periods, and herein our information is most at fault. Nevertheless we are not altogether without intimations of organic changes. The majority of physiologists are agreed that the function of the cortical substance is of a higher character than that of the medullary. The lower we descend in the animal series, the less we find of the cineritious matter, which is not apparent at all in the invertebrata, nor indeed in fishes. It is, therefore, not without probability conceived that this matter is more immediately concerned in thought; and, conformably with this view, we find its colour more strongly marked, as boyhood stretches on to manhood.† We may mention as corroborative of this circumstance, that M. Foville, an eminent investigator of the pathology of mental diseases, asserts that the principal lesions in the brains of maniacs occur in the grey tissue.‡ The convolutions again afford us some hints upon the subject before us. Intelligence is in direct proportion to their extent, and we accordingly find that these parts are deeper as age advances. As the existence of the posterior cerebral lobes, and of the corpus rhomboideum in the cere-

* See the notes to Milligan's Translation of Magendie's Physiology.

† This observation refers to the cineritious matter of the convolutions. In certain other parts this substance diminishes after birth. Thus, in the full-grown fœtus, the medulla oblongata is grey throughout, but soon begins to whiten, first in the corpora pyramidalia, and afterwards in the olivaria. The outer surface of the tuber annulare, and of the crura cerebri, is also grey at the commencement of extra-uterine life; but they lose this colour after a few weeks. In the thalami optici and corpora striata there is no distinction of white and grey matter, the latter alone being visible. See Meckel, Manuel d'Anatomie, t. ii. p. 717. Till the functions of these parts in mature age are better understood than at present, it would be useless to speculate upon the physiological relations of the changes which they undergo in earlier periods.

‡ Dict. de Méd. et Chir. Pratique, art. Aliénation Mentale.

bellum, is observed only at the top of the animal scale, we might expect that in the progress of age there would be a change in the relations of these parts to the whole mass, but we cannot find that any researches have been prosecuted in elucidation of these points.

Most of what we have predicated of the progressive actions in the brain, is likewise applicable to the cerebellum and spinal marrow, and nerves. The latter parts, however, are more forward in their organization, being devoted to the more primitive functions of sensation and voluntary motion, while the former is the instrument of the faculties more eminently intellectual. The proportion of the cerebellum to the brain at birth, is, according to Meckel, as 1·23; the former weighing nearly $3\frac{1}{2}$ drachms, the latter 9 or 10 oz. A month after birth the ratio is 1·17; after six months, 1·8.

The proportion between the spinal marrow and the brain at birth, and for five months after, is 1·107 or even 1·112; the brain at the former period weighing 9oz. 4dr., and the spinal marrow 45gr., while at the latter period the cerebral organ weighs 21oz., and the spinal $1\frac{1}{2}$dr. In the fœtus of five months the proportion is 1·63, of three months 1·18. In the adult it is 1·40. The diminishing ratio of the brain to the spinal marrow is in obvious harmony with the elongation of the vertebral column, and with the general growth of the members. The medulla oblongata is proportionally larger in early than in advanced life; the corpora pyramidalia and olivaria being distinct and prominent; a fact which corresponds with the development of the brain.

The longitudinal dimensions of the corpora quadrigemina at birth exceed those of the adult period; after the former period they increase only in their transverse diameter.

The concretions of the Pineal glands have not begun to be formed till the seventh year. They are sometimes wanting in very advanced age, according to the observations of Meckel and the Wenzels, which we have had opportunities of verifying by our own dissections. The number of these bodies increases with the progress of life, and their colour is paler in youth and old age than in intermediate periods.*

So much then for the nervous organs of sensation. Our attention must next be directed to the mechanism intermediate to the nerves, and the excitants of sensation. The simplest kind of sensation is that which informs or reminds us that we are possessed of bodily parts, such as members and internal organs. The mechanism employed, if there be any, is unknown. Nerves are distributed through the tissues, we feel those tissues, and conclude that these feelings result from relations between the nerves and the other textural molecules with which they are in contact. These feelings must of course vary with age because the tissues alter, but whether the susceptibility is increased we cannot say, and only venture to remark that the probability of this being the case is suggested by the fact, that adults are more subject to perversions of sensibility than children; witness the various nervous, hypochondriacal, and hysterical disorders with which adults are almost exclusively visited.

The next order of sensations in respect of simplicity are those of tact, or those by which we are made acquainted that foreign bodies are in contact with our skin. It is perhaps in some respects only a modification of the first-mentioned sensation, but it requires the presence of something not belonging to us. It is true that other parts than the skin may convey the notion of an external body being applied to them, but they do not afford any perception of the qualities of the body; it is merely the affection of themselves which is produced by that body. We are aware that all sensation may be analysed in the same manner with similar results, but it is enough for our present purpose that the sensation excited on the skin is less *selfish*, if we may use the term in this sense, and ought to be so, in order that it may serve its office of supplying some knowledge of the external world. Doubtless the organization of the epidermis and of the skin itself, as well as the greater distribution of nervous matter, occasion the difference. The dermoidal tissue in modifying the external cause stands in the same relation to the nerves of tact, as the eye to the optic nerve, or the nose to the olfactory. The organ of tact is affected by age; the skin in very early life appears less susceptible of impressions, and differs in its tissue, the papillæ being less developed. A change, however, is soon effected in this respect, and as we advance towards manhood, it becomes less gelatinous and more fibrous. It must be confessed, however, that the modifications which it undergoes in reference to its function of sensation, are not well defined. This circumstance is owing to the variety of sensations to which it ministers, such as (in addition to what we have mentioned) feelings of heat and cold, dryness and moisture, &c. and, secondly, to its being also an organ for other and very different functions, such as transpiration, secretion, and absorption.

Touch has a far more complicated mechanism than tact. It is one of the senses properly so called, or the special senses, and like the others of its class *is distinguished by its requiring the assistance of muscles.* Its sensations are compounded of tact and muscular resistance, and the organ is that wonderful instrument the hand. The imperfect state of this organ in infants must have been noticed by every one; it is generally closed and capable of grasping but very feebly; at all events a long time occurs before the little being learns to arrange the sensitive tips of the fingers, and to adjust the thumb in such a manner as to ascertain with nicety the form, consistence, and other properties of bodies. Whether the skin is less sensitive in these subjects we cannot say, but it is quite certain that the muscles, which effect the digital motions alluded to, are not developed any more than those in other parts of the body. Fine-

* For further details see the works of Meckel and Tiedemann.

ness of touch, tactus eruditus, is one of the most difficult attainments of manhood.

Concerning the alterations in the olfactory apparatus we have already spoken, when the development of the facial bones was under consideration. The sense of smell is manifested pretty early, but there can be no great precision and nicety in its exercise, both from defect of surface, and from the want of muscular power and command, in adjusting the quantity and impetus of the air that conveys the odorous particles. Thus, some agents are only appreciated by a sudden inhalation through the nostrils, as if to bring the particles with a certain degree of force upon the Schneiderian membrane. This art the child does not understand.

Taste being a sense so essential to the maintenance of the system, whether by inducing the animal to take the trouble of eating, or by warning him of improper aliment, is manifested very early. The usual description of the mechanism of taste would give just cause for questioning what was said respecting the necessity of a co-operation of muscular action with the five senses. Taste is described as the result simply of the application of sapid bodies to the tongue, palate, velum palati, &c. But these bodies excite no sensation without the aid of muscles. A certain degree of compression is necessary, which is accomplished by pressing the tongue against the roof of the mouth. Any one may assure himself of this fact by placing a strongly flavoured substance on the tongue when projected from the mouth; no taste will ensue till the member is withdrawn and then pressed against the palate. This observation applies not only to the tongue but also to the palate itself, and that sensitive surface the velum. In each instance, however, the effect may be imitated, by compressing with the finger the part where the substance is applied.

Taste must undergo a progressive development correspondently with the muscular organs. It is, to say the least, very doubtful if a child could perform those delicate manœuvres of the tongue and palate, which are practised by gourmands or professed wine-tasters. There is something more than this muscular action, however, to be taken into consideration. The more refined flavours are probably felt and estimated by the lining membrane of the nasal passages. It is common to remark that the scent of a substance is similar to its taste, but in all probability the two sensations are identical; for the taste in question is not perceived if the nostrils be closed; witness the abolition of taste during a catarrh. If therefore so close a connection exists between the two senses, it is clear that the development of the organization belonging to the one must influence the other function; and it has been already pointed out that the olfactory surface increases with growth.

The new-born infant is probably all but deaf; even the loudest sounds produce no sensible impression. The nurse's lullaby, therefore, is for some time superfluous; by degrees, however, the shrill tones, of which such strains for the most part consist, begin to be appreciated; the precise period however we do not know. In correspondence with this obtusity we find the organ incomplete, but the incompleteness has reference rather to the external than to the internal ear. Thus the pinna is very inelastic, and therefore unfitted for collecting vibrations; the same may be said of the meatus auditorius. In like manner, the membrana tympani is very oblique, and scarcely more than a continuation of the superior surface of the meatus, and thus little calculated to receive the vibrations. These parts are also covered with a soft matter very unfavourable to vibrations; the tympanum is very small, and the mastoid cells do not exist. In the progress of age all these parts gradually increase in hardness, and consequently are better adapted to their function. There are muscles attached to this sense also, but we are deficient in observations on their degree of development, though we may infer their condition from analogies in the rest of the muscular system.

Lastly, we come to the organ of vision, of which, however, there is not much to be said. The differences between the visual organ in the infant and in the adult consist more in degree than in kind; thus the sclerotic membrane is less elastic, and the cornea is less conical, in consequence of the smaller quantity of aqueous humour; (the greater thickness of this coat is produced by the serosity contained between its laminæ;) the crystalline lens is less dense, but more convex in form. The pigmentum is in smaller quantity at birth than afterwards; while the retina is thicker and more pulpy than in more advanced periods. The yellow tint of the foramen of Soemmering does not become visible till some time after birth, but deepens with the progress of life, till the stage of decline, when it grows paler. It has been ascertained that perfect images are formed on the retina; and yet for the first few days the child gives no indication of visual sensation, and when objects appear to attract its attention, they are only those which are vividly illuminated. The deficiency therefore must exist in the optic nerve, though we are ignorant of the organic condition on which this insensibility is dependent. We observe, moreover, that the eye is much more passive than in the adult, that it follows the motion of luminous bodies, or is fixed upon them with little or no apparent interference of the will. This muscular incompleteness, then, tallies with what we have noticed with respect to the other senses. The eye is known in its advance towards manhood to increase in the capability of adapting itself to different distances; but as we are ignorant of the mechanism made use of for this purpose, it is useless to look for corresponding organic alterations. We must not omit to notice those appendages to the apparatus of vision, called eyebrows, which become much more prominent as life advances, by the development of the frontal sinuses, and are therefore better adapted for shading the eyes.

The generative apparatus is situated intermediately to the animal and the organic system.

The evolution of the organs connected with this function marks the age of puberty; and the changes in which this evolution consists, both in the male and in the female, are too well known to require their specification here. The influence of this development on the mental and moral characters of either sex, is likewise sufficiently familiar even to the most superficial observer.

The human being is related with the external world passively and actively, independently of those organic actions and reactions that are constantly occurring in his system with regard to outward agents. He derives perceptions from objects about him, and he reacts on them by his power of muscular motion. But in his growth we mark that the perfection of those organs, which are scarcely more than passive in his *relative* life, advances much more rapidly than those which enable him to take a more active part. Thus the eye and the ear attain a certain maturity of organization and function, long before the bones and muscles, which officiate in locomotion. The bones and muscles connected with the organs of sensation, and therefore partaking of the passive character, are also equally forward in their development. What is the probable final cause of this arrangement? If all our voluntary motions were the immediate consequences of our sensations, as some of them undoubtedly are, such as those which close the dazzled eyes, or refuse the bitter food, or withdraw from painful contact;—if all these followed directly on sensations, it would indeed be a strange anomaly, if the systems that belong to each were not precisely on the same level of development. But this is not the case; all the more important motions, important as it regards that world in which man exists, as an intelligent and social creature, though less so as it respects his individual being, are the results of a mental condition, no less distinct from sensation than from muscular motion. This state is desire, or as it is commonly called when the antecedent of action, will or volition. Probably no mental state is more simple than this, and it may follow any other. It is therefore the more necessary that it should be preceded by such intellectual changes as will give it a right direction; in other words, that it should come under the dominion of certain faculties. But in early life the faculties to which we allude are very imperfectly developed; those only have attained any thing like maturity which are in immediate relation with the senses; such are perception, memory, association, and imagination; while the reflective faculties, such as comparison, reasoning, abstraction, all in fact that constitute man a judicious experienced agent, are rudimentary. The consequence is that the desires or volitions are proverbially vain and dangerous. Let us observe a child of seven years old; his senses are sufficiently acute for all ordinary purposes, although they are deficient in precision and delicacy; he has seen many attractive objects, he has heard many wouderful stories, and tasted many exquisite delights; he remembers them vividly, he associates them rapidly, and often in shapes very different from those in which they were formerly combined. Desires follow which would prompt him to execute the most ridiculous and mischievous schemes. But happily the muscular system, by which alone he could accomplish them, is too immature and feeble for his puerile purposes. Here then is the final cause that we were in search of; the *active* corporeal functions of relation must not advance beyond the governing faculty of the mind.

But why, it might hastily be asked, should not the senses, the mental faculties, and the motive powers, all have been equally developed? The question is absurd, if we consider but a moment the manner by which the mind accomplishes its growth; that its higher powers result from the accumulation of innumerable sensations, by which in fact the former are nourished and exercised.

We shall now introduce a brief account of some researches upon the *height*, *weight*, and *strength* of the human body, at different ages, prosecuted by M. Quetelet, of Brussels. Not having room for the numerical tables, or the particular observations, from which his general conclusions are derived, we must content ourselves with a statement of the latter, and refer those of our readers who may be desirous of seeing the former, to the author himself. His deductions as to the growth of human stature are as follows: (1) the growth is most rapid immediately after birth; it amounts in the first year of infancy to about two decimetres (nearly eight inches.) (2) The growth diminishes as the child advances towards the fourth or fifth year; thus, during the second year his increase of height is only half what it was the first year, and during the third year it is not more than one-third. (3) After the fourth or fifth year, the stature increases pretty regularly until the age of sixteen, and the annual growth is about fifty-six millim, (two inch.) (4) After puberty the stature still increases, though slightly; thus, from the sixteenth to the seventeenth year, the increase is about four centim. ($1\frac{3}{5}$ inch); and in the two following years, only two centim, and a half (one inch.) (5) The stature does not appear to be quite completed even at the age of twenty-five.—These observations refer only to absolute growth, but if the annual increase of stature be compared with the height which has been attained, it will be found that the infant, after birth, increases in the first year by two fifths of his height; in the second by one-seventh; in the third by one-eleventh; in the fourth by one-fourteenth; in the fifth by one-fifteenth; in the sixth by one-eighteenth; &c. so that the relative growth continually diminishes after birth.

In addition to these statements M. Quetelet has ascertained that the rules of growth are not the same in both sexes; 1st, because the female at birth is less than the male; 2dly, because her development is completed earlier; 3dly, because her annual growth falls short of that of the male. It appears likewise that the stature of persons living in towns, taken at the age of nineteen, exceeds that of residents in the country by two or three centim (1 or 1¼ inch); and that the children of persons in easy circumstances, and those of studious habits, are generally above the middle height.*

A memoir by the same author devoted to an examination of the weight of the human subject at different ages, contains a series of interesting conclusions, from which we select the following. (1.) At the period of birth there is an inequality both as to weight and to stature, in the two sexes; the medium weight of males being 3 kil. 20, (rather more than 7 lbs.), that of females 2 kil. 91, (about 6½ lbs.); the height of the former Om. 496, (about 19 inch.); that of the latter Om. 483, (about 18 inch.) (2.) The weight of the infant *diminishes* the first three days after birth, and does not begin to increase till the second week. (3.) At the same age the male is generally heavier than the female; it is only about the twelfth year that their weights are equal. Between the first and eleventh year the difference of weight is from 1 kil. to 1 kil. and a half; between sixteen and twenty, about 6 kil. and after this period from 8 to 9 kil. (4.) At full growth the weight is almost exactly twenty times what it was at birth, while the stature is only about three and a quarter more than it was at that period. This holds good with both sexes. (5.) In old age both sexes lose about 6 or 7 kil. of their weight, and 7 centim. of their height. (6.) During the growth of both sexes, we may reckon the squares of the weights, at the different ages, as proportional to the fifth powers of the heights. (7.) After full growth in each sex, the weights are very nearly as the squares of the heights. (From the two preceding statements it may be deduced that the increase in the longitudinal direction exceeds that in the transverse, including in the latter both width and thickness.) (8.) The male attains his maximum weight towards the fortieth year, and begins to lose it sensibly towards the sixtieth. The female does not attain her maximum weight till about the fiftieth year. (9.) The weights of full-grown and well-formed persons vary in a range of about 1 to 2, while the heights vary only from 1 to 1⅓. This statement is deduced from the following table:†

	Maximum.	*Minimum.*	*Medium.*
	KIL.	KIL.	KIL.
Male weight	98.5	49.1	63.7
Female	93.5	63.7	55.2
	MET.	MET.	MET.
Male stature	1.990	1.740	1.684
Female	1.740	1.408	1.579

* Recherches sur la loi de la Croissance de l'Homme, par M. Quetelet. Annales d'Hygiène Publique, &c. t. vi. p. 89.

† Ann. d'Hygiène, t. x. p. 27. To the above memoir M. Villermé has appended some extracts from manuscript notes found among the papers of M. Tenon, and written about the year 1783. They contain observations which correspond, in many respects, with those of Quetelet.

The last researches of this industrious observer have been devoted to the muscular power of man at different ages, and have been but very recently published. In the course of his memoir he refers to two tables; one stating the relative power of draught (la force rénale), at the several periods; the other, the relative manual strength (la force manuelle); in each case estimated by the dynamometer. The results are very much what might be expected à priori. It appears that the maximum of the "force rénale" is at the age of twenty-five; and that the difference in the extent of this kind of muscular power between males and females, is less during childhood than at the adult age. Thus, in the former period the male surpasses the female by one-third, towards puberty by one-half; and at full growth, his strength is double that of the other sex. The manual force is greatest at the age of thirty, and at all ages is greater in the male than in the female; before puberty, in the ratio of 3 : 2, after this period, in the ratio of 9 : 5. The average manual strength of a man is equivalent to 89 kil. and exceeds his weight by 19 kil., so that he might support himself by his hands only, even with a considerable weight attached to his feet.*

This and the preceding memoirs, we are told by M. Quetelet, are extracted from a work which he is about to publish, entitled "Sur l'Homme et le développement de ses facultés; ou, Essai de Physique Sociale." We need scarcely add that we are justified in expecting from the specimens already presented to us, a series of valuable and highly interesting facts, together with deductions of no ordinary importance and originality.

Having thus briefly traced the changes that precede maturity, we may ask what is it that prevents the processes of growth from advancing at the same rate as they have hitherto done? Why, so long as they are undisturbed by disease or unnatural circumstances, should they not advance ad infinitum, or at least why should they not raise man to the strength and dimensions which poets have fabled in their Titans? The same food, the same atmosphere, the same light and heat, the same electric agencies, by which the organs have been maintained or excited, are still around them and exerting their influence. Why, then, should they never transcend a certain point? Why should the stature, however much it may vary between a Boruwlaski and an O'Brien, yet never rise above a certain measure? Why does the strength never exceed the powers of a Milo or a Desaguliers, or the intellect surpass the limits of Aristotle, Shakspeare, or Newton? These are interesting but impossible problems. If we say that a certain quantum of vital power is allotted to the growth of man, and that while a portion is expended in raising him to maturity, the residue must be husbanded for conducting him through the remaining portion of his duration, else he might suddenly stop short

* Ann. d'Hygiène, &c. Oct. 1834, t. xii. p. 294.

in his career without passing those stages that prepare him for the cessation of his existence; —what do we gain by such an explanation? Nothing; for the term vital power which we employ is but a hypothetical cause, or if more closely examined, is scarcely even this; it is but an abstract term applicable to a number of actions that do not occur in the inorganic world. The vital power of a body is but the collective manifestation of its vital actions, and to say therefore that only a certain quantum of vital power is inherent in it, is but to express in other words the simple fact that those actions are circumscribed. Discarding this explanation, shall we say that the fact must be referred to some deficiency in the media of the being's existence; that, although the aliment, the air, the light and caloric are competent to the production of a certain degree of growth, they cannot extend it, and that, were their conditions different, the animal development would be more perfect. It is easy perhaps to suppose this, but we do not see how it can be proved, nor indeed that existing analogies favour it. On the surface of our globe there is every variety in the temperature, in the humidity, and in the electric conditions of the atmosphere, and every diversity in the articles of food employed; in more limited spheres there are the greatest diversities in these several respects produced artificially by the various occupations of mankind; and although we find, both among races and individuals, great varieties of development, which may occasionally be traced to some relation with the media in which they live, these varieties are by no means in proportion to the differences of the media, and in the majority of cases the former are independent of the latter. In the temperate zone, with a due proportion of animal and vegetable diet, man appears to attain his most perfect development, and with however great skill he adapts these circumstances, he never surpasses a certain point, and from what we know of his physiology no great alteration in any one of the external stimuli of his existence could be tolerated. A different proportion of the oxygen, nitrogen, and carbon in the atmosphere, we know full well to be noxious; a larger or smaller quantity of aqueous vapour suspended in it will occasion many well-known maladies; the same may be said of alterations in the balance of the electricity that surrounds us. Great extremes of heat and cold may be borne for awhile, but it is obvious that they are not so well adapted to a healthy state of the system, and therefore to its growth, as intermediate degrees; and consequently it is not easy to conceive any degree either above or below these limits consistent even with existence. Familiar enough also are we with the effects of full and sparing, of simple and mixed dietetics, and with the fact that between certain well-known bounds lie the salutary quantities and qualities. From all which it appears sufficiently evident, that we cannot conceive any difference in the amount or properties of the known stimuli of life, that would be more favourable to the growth of man, than those which are to be found in the range of the known variations, whether natural or artificial. From the beginning there must have been established a direct relation between the organization of the body and the outward elements; the latter are nothing but stimulants adapted to co-existing susceptibilities, or to put it more closely, man is not made by, but for or with, the surrounding agents; his lungs are fashioned in correspondence to the atmosphere which he breathes, his digestive organs to the food that is spread so plenteously before him, and his nervous system to the subtle imponderable agents that play about him; consequently as his organs only act in concert with, and do not result from the media of his existence, a development beyond that which he is known to acquire must proceed quite as much from the former as from the latter; and the supposition, the value of which we have been endeavouring to estimate, thus falls to the ground. If man could become a larger, more powerful, or more sagacious animal than he now is, he must not only live in different media, but must possess a different constitution; in other words, the characters that distinguish him as a species must be altered. The question, then, that offered itself remains to our apprehension unsolved by either of the hypotheses. The limitation of man's development is like the definite period of his duration, and a hundred other circumstances connected with his existence, an ultimate fact; no event that we are able to discover intervenes between its production and the will of the Deity.

Maturity, though varying with every individual, may be said to take place somewhere between the ages of twenty-five and thirty. It is a general opinion that it is a stationary condition; that when such changes have taken place in the frame, as render the human being capable of undertaking the various duties and occupations to which adults alone are adequate, there are no further alterations till the period of declining age; that, in short, growth has entirely ceased. But this idea is not strictly correct, for there is in all probability no period when the system is absolutely stationary; it must either be advancing to or receding from the state of perfection. This is of course more obvious when we know that augmentation of bulk is only a part of that process which perfects the organization. (See Nutrition.) It is true that at the adult age the determinate height and figure, the settled features, the marked mental and moral character, naturally give rise to the idea that a fixed point has been attained; but a little inquiry soon teaches us that the individual is still the subject of some progressive changes. It is the stature only that is stationary, for this depends on the skeleton, which ceases to lengthen before the period we speak of. But the capability of powerful and prolonged muscular exertions increases for some years; there must consequently be a change in the muscular tissue. The intellectual faculties have not attained their maximum, although we do not hesitate to consider them mature; we must therefore infer that there is a corresponding organic development of some kind in the cerebral substance. Maturity then would, according to this view, require to be dated at a period much later than that which is usually assigned to it. It is enough, however, without referring further, to know that although at the adult period the organs of animal life are so developed, that we cannot consider them imperfect instruments, they are even afterwards the subjects of a *perfectionnement*. What is commonly meant then by maturity, is in strictness that period of human existence, during which the processes of growth and decline are passing into each other by such slow degrees as to be imperceptible.

In this important era of the life of man, more important even than the season of adolescence, we must leave him in the full possession of all the faculties and energies which his Maker has allotted him, fulfilling his destiny of good and evil, encountering and triumphing over peril, toil, and pain, scaling the rough steep of ambition, threading the dark intricate paths of gain, labouring for the happiness or misery of his fellow-creatures, supported all the while by the consciousness of a strength that seems never to fail him, of resources never to be exhausted; we must allow a few years to roll by, and then return to him, when weary, wayworn, and broken with the storms of life, he has discovered that there are limits to his powers of action and endurance; that of the objects which he proposed as the ends of his labours, while a few have been accomplished, the majority are either vain or unattainable; and that a race fresh in vigour, and high in hope, the images of his former self, are overtaking and thrusting him away from the scenes of his exertions. What are the revolutions that have transpired in his system?

The formative organs of all the tissues of the body are in reality the tissues themselves; whether it be a muscle, or a gland, or the coat of a vessel, the parts which essentially produce its growth are nothing more or less than its own constituent molecules, the mutual attractions of which in deposition and absorption constitute assimilation; for there is no proof that vessels are used for any other purpose than that of conveying the nutrient fluids to and from the places, where the ultimate molecules arrange themselves in the form of tissue. The altered qualities, then, which are presented by the tissues, in whatever organs, in the decline of life, must depend immediately upon alterations in their own molecular motions and affinities. The nature of these alterations will of course correspond to the nature of each tissue; and unless we mistake, they will all be found to agree in one character, viz. a simpler composition, a lower kind of organization than they formerly possessed. But the discussion of this point will be more conveniently deferred till we shall have briefly recited the principal changes in the more important parts of the body.

As the nutritive secretions of the various structures are supplied with materials by the fluids in those structures, it is evident that they must at any time be increased, diminished, or otherwise modified by changes in the quantity and properties of these fluids. It is therefore a natural commencement of the subject to begin with the circulating system.

Nothing is more obvious in the condition of the aged as contrasted with the young than the different ratio between the fluids and the solids, the former being remarkably deficient. There is not only a notable diminution in the quantity of oleaginous or serous secretions, which are generally contained in the cellular parts of the body, but it is manifest that the tissues are permeated by a much smaller proportion of blood. This fluid moreover is very different in quality from what it was in earlier life; it is less arterial, its colour has not the same bright red it once presented, it has a large proportion of serum, and its coagulum is less firm in consistence.* Correspondently with the deficiency of fluids, many parts which once contained them are shrunk or obliterated. The capillary system becomes infinitely less extended than it once was; many of the extreme branches of the arteries themselves are no longer to be penetrated, and those which remain pervious, are far less distensible than formerly. There is indeed a remarkable change in the coats of these vessels; they are not only contracted in diameter, but are become denser and more rigid in texture. In this respect they differ from the veins, which in old age are more dilatable than in youth, and consequently contain a larger quantity of blood. The final cause of this is evident; in youth the arteries must convey a relatively larger quantity to supply the increasing structures; in the decline of life, when the latter are decreasing, there can no longer be any need for the same supply; the permission, however, of an accumulation in the veins, where it is less likely to be productive of injury, appears to be an accommodation to the diminution of the circulating powers.

If we trace the arteries from their extremities back to the heart, we shall find their calibres every where diminished, their coats less elastic, less capable of adapting themselves to the varying quantity of their contents, in some places resembling the texture of ligament, in some that of cartilage, and in others studded with deposits of osseous matter. The heart itself presents marks of degeneration no less decided; its cavities are shrunk, its fibres pale, and but feebly contractile, and fat will sometimes seem to take the place of the muscular substance. Frequently, also, the coronary arteries are found ossified, and the same alteration is not uncommon in the valves.

All these facts account for the slow, languid, staggering circulation characteristic of advanced life; there is less blood to be transmitted to the various organs, and that which is sent is propelled with a degree of feebleness that shows how little energy is required in its motion, when

* De Blainville is of opinion that these changes are exaggerated. Cours de Physiologie, i. 262.

so few nutritive actions are transpiring. We have spoken of the altered character of the blood, of its being less arterial and of a darker tint: this change is explained by the alteration in the respiratory system. The lungs are become lighter, the cells being relatively much larger,* and the parenchyma, which consists principally of bloodvessels, being greatly diminished. This alone would not explain why the blood is imperfectly arterialized, because, although the respiratory surface is diminished, less of that fluid enters the organ. But the bronchial membrane is always in a more or less unhealthy condition, being covered with a thick and copious secretion, that constitutes the "old man's catarrh," and prevents a due intercourse between the air and the blood. Besides this circumstance, the expansion of the chest is less perfect in consequence of the diminished elasticity of the parietes of the chest produced by the ossification of the cartilages and other causes: the muscles also participate with less energy in the respiratory movements. Every thing in the history of advanced life indicates the diminution in the vigour of the circulation and respiration. The apathy and languor of mind, the deficiency of many secretions, and the general decrease of animal heat, but particularly in the parts most distant from the heart, are all more or less intimately connected with the failure of these vital actions.

On turning to the digestive apparatus we have abundant marks of deterioration. The teeth fall out, the alveolar processes are absorbed, and the gums become hardened. In addition to these there is a change in the muscularity of the stomach; it has become weak, attenuated, and less contractile. The same is true of the intestines. The lacteal vessels are much fewer in number, and scarcely any lymphatic glands are to be met with. Every thing intimates that the food is less perfectly acted upon, and that consequently less chyle is extracted, and transmitted to the circulation.

Since, then, in these several systems, we find marks of diminution, impairment, depravation, it is not wonderful that nutrition, which is performed by means of the materials supplied by those systems, partakes of the same characters. But as nutritive changes must have occurred in the various deteriorated parts just spoken of, it would be incorrect to say that alterations of tissue depend solely on the alterations of these systems, though they are promoted by them; they must, in fact, have assisted each other. The altered tissues could not have been easily thus changed, without a defect in the quantity or quality of the matters out of which they are formed; nor could the latter defects have easily occurred without some alteration in the texture of the parts employed in conveying and elaborating the nutrient fluid. It is an old saying, that the functions of the body form a circle: if this be true of their healthy condition, it is not less so of their diseases and decline.

The organs and tissues subservient to the organic life having undergone vitiation and diminution, we may expect to find equal or even greater decay in the parts which are altogether dependent upon them, or the organs of the supplemental life. These indeed, as they are the last to be developed, are some of the first to present marks of decline, and evidently for the same reason, viz. because they are appended to and generated by the other parts of the system, and also are more open to our observation. The body is indeed, in this respect as in many others, not unlike a political community; no great change can occur in its internal arrangements, such as a failure or derangement of its energies and resources, without a manifestation of this weakness or disorder in its foreign relations.

Let us proceed, then, to examine the ravages which are wrought by the hand of time on the organs of locomotion and sensation, in the same order in which we have traced the developments and amplifications, once lavished by the self-same agent.

And first of the bones. The process of development in these parts consisted of a certain adjustment of the animal to the earthy matter, in order to give the requisite firmness, toughness, and solidity. As life advances, the phosphate and carbonate of lime are found to exceed the proportion of the cartilage and gelatine. The general conformation of the bones is less regular; they look shrunken and worn. When handled they feel lighter, notwithstanding the osseous substance is in excess; a fact, which results from the diminished quantity of the fluids, and one or two other circumstances to be mentioned presently. The processes and ridges, once so eminent and distinct, are comparatively effaced; this alteration accords with the wasting and diminished exercise of the muscles that were attached to these eminences. On looking for the lines and spaces, which are occupied in early life by cartilages or membranes, and which are visible even in manhood, we now find every trace of them vanished. Thus, the divisions between the epiphyses and shafts of the long bones, the line of union between the bones of the pelvis, and, in a still more marked degree, the sutural outlines of the bones of the head, are no longer perceptible. They are all filled up with bony deposit, and the pelvis and cranium form single bones; even the foramina by which the nutrient arteries entered the tissue are contracted or obliterated. The cellular structure between the tables of the cranium is removed;

* M. Andral, in his description of the atrophy of the lung which occurs in aged persons, says, "In some cases the walls of the cells disappear altogether, and we only find in their stead some delicate laminæ or filaments, traversing in different directions cavities of various sizes. In the parts of the lung where these alterations exist, there are no longer to be found either bronchial ramifications, or vesicles properly so called, but merely cells of greater or less diameter, divided into several compartments by imperfect septa or irregular laminæ. Many of these cells bear a perfect resemblance to the lung of the tortoise tribe, and they all approach to it more or less as to a type of organisation, towards which the human being in this case seems to descend. Pathol. Anat. v. ii. p. 528, translated by Drs. Townsend and West.

and the outer plate has approximated and indeed become identified with the inner; hence we see more depressions on the surface of an aged skull.

On inspecting the internal structure of these organs, we find the cavities that contain the marrow much more extensive than formerly, and the medullary tissue reduced to a consistence scarcely exceeding that of oil. The cells also of the short bones and of the extremities are more expanded, and the laminæ which form them are very much attenuated.

The deficiency of animal matter renders the bones of the aged fragile; they are broken by the most trivial accidents. It is also the cause of their slowness to unite; for the activity of assimilative, and consequently of reparative processes, is dependent on the vascularity and fluidity of a tissue. The lightness, however, of these organs produced by the same cause is beneficial, or at all events in harmony with the state of the muscular system.

If we next turn our attention to the articulations, we shall find that similar processes of disqualification for former functions have ensued. The spinal column, which once adapted itself with such ease and flexibility to the motions and curves of the body, has become almost as rigid as a single bone by the drying up of the intervertebral cartilages, and sometimes by the encroachments of ossification.* Scarcely any traces of cartilages between the ribs and the sternum can now be found; one of the causes to which we alluded above, in connection with diminished respiration. The same deficiency of cartilage is observable in the bones of the wrist and of the tarsus. A change, the opposite of mobility, may also be detected in the ligaments which embrace the joints; they are dense, dry, and inelastic. The gelatine which enters so largely into their composition has become altered in its chemical properties; it is less easily soluble in water, and has all the characters of glue rather than of jelly. Ill-adapted as this state of the articulations is to the purposes of motion, it is, we think, not altogether difficult to discern its appropriateness to the human being at this advanced period. Were the joints supple and flexible, while the muscles have so little power, how much greater would be the risks of accidents to the aged man in the slight motions which he achieves. In order to preserve their frames from falling, those whose joints move easily upon each other are compelled to exercise those muscles which keep the limbs in the requisite degrees of extension and stability, during certain attitudes and motions; but this end is accomplished in the feeble old subject by the very stiffness of his articulations.

The muscles are subject to changes no less decided than those in the organs just mentioned. They are pale, flabby, atrophied, and indisposed to contract on the application of stimuli; but the fibre itself is tough and not easily torn, and the true muscular substance seems to have given way in some places to a sort of dense cellular membrane, or a yellowish degeneration of tissue particularly described by Bichat. Their tendons are often studded with calcareous matter, and the sheaths in which they play are rigid and unmoistened with synovia. They obey the stimulus of the will tardily and irregularly; the uncertain tremulous movements, the tottering gait, the stooping posture, the unsteady grasp of the aged, are familiar to every one.

The organ of voice comes next to be considered. The larynx, once composed of several cartilages that moved freely on each other, is now a cavity capable of much less variation in its dimensions, owing to the rigidity of its parietes; the extent of the cavity gives in early old age that depth of tone, which by its gravity and solemnity excites our homage. In more advanced age, however, the tone becomes hoarse, shrill, and piping; this in all probability is produced by the contraction and stiffness of the rima glottidis, but still more by the want of vigour in the muscles of the mouth and throat. The incapability of managing the tone, and the tremulous articulation, are also results of changes in the muscles of the larynx, pharynx, and tongue, similar to those which transpire in other parts of the muscular system. Many senile impediments of speech are also produced by the loss of teeth, by the falling in of the cheeks, and by the disproportion of the lips to the space which they occupy.

In our investigation of the signs of decay in the parts that are subservient to sensation and thought, we shall be met by the same difficulties which formerly opposed our way, when inquiring into the phenomena of their development. We traced the progress of the nervous substance both in the nerves and in the cerebro-spinal centre from the almost pulpy state recognized in the infant, to its firm consistence in the adult. If we now investigate the anatomical quality presented by the tissue in advanced life, we shall find that it has shared the alteration of nearly all the other tissues,—that in short it has increased in density. This fact viewed in connection with another, namely, that ramollissement and induration produce very nearly the same lesion of function, will account for the failure in the sensific powers of old age. Besides this alteration in the substance of the nerves, they are found to be diminished in diameter; their neurilemmes are become, like other membranous parts, much harder and stronger. Moreover, Bichat has remarked that the nervous tissue of old ani-

* "Cependant il est rare que les fibro-cartilages s'ossifient chez les sujets avancés en âge. A la verité on voit souvent les vertèbres se réunir avec les autres au moyen d'une substance osseuse, mais cette soudure dépend bien plus rarement de l'ossification des fibro-cartilages que de la formation de lames osseuses à la circonférence des deux faces par lesquelles se regardent les coups des vertèbres. Cependant j'ai observé quelquefois aussi l'ossification des fibro-cartilages intervertebraux, et j'ai trouvé alors, en sciant longitudinalement la colonne épinière, que plusieurs vertèbres étaient soudées ensemble, et confondues en une seule masse."—Meckel, Manuel d'Anat. t. i. p. 364.

mals is much less easily affected by reagents than that of younger ones; so that there would appear to be an alteration in the chemical composition as well as in the mechanical consistence.

That which has been said of the matter of the nerves is also true of the brain. The whole bulk is diminished and the density greater than in earlier years. Some, however, assert that it is even softer than in manhood. M. Blandin makes a remark of this kind, in commenting upon Bichat's statement of a greater hardness in the tissue, and says that it might be expected *à priori*, since there is so strong a correspondence between the two extremes of life. There is reason, however, to think that this remark, if true at all, applies only to the cerebral organ of persons very far advanced; and it is not improbable that diseased softening has in other cases been mistaken for the natural effect of age. The membranes investing the brain like the neurilemmes (for they belong to the same system) are also thicker and more resistent. The vascularity of the organ is greatly diminished; on a divided surface no red dots are visible as at periods less advanced.

The alterations in the mechanism of the senses must next be considered. The skin, which is the medium between the nerves of tact, and external agents, undergoes great changes in the progress of life. It becomes drier, harder, less flexible, and at the same time looser, in consequence of the absorption of the adipose substance. By the latter qualities the function of the skin is more evidently impaired, in that modification of it more expressly denominated touch, or the sense of tact united with certain muscular feelings in the fingers and hands. By the looseness of the integuments, the slowness and weakness of the muscles, the stiffness of the digital joints, and that dulness of sensation which exists in this as in every other part of the system more or less, the hand is notably deteriorated in old age.

In the olfactory apparatus we find that, although the cavities and sinuses, through which the Schneiderian membrane is extended, are rather increased than diminished in size, the membrane itself is attenuated and less pulpy. The nerve also is mentioned by Rullier* to be evidently contracted and wasted.

The sense of taste so closely connected with that just spoken of survives to the extremest limit of existence; the final cause of which is evident. It is too intimately connected with one of the processes of organic life to be easily dispensed with, although one of the functions of the superadded life. It is, however, feebler than at periods less advanced, and requires the excitement of more piquant aliment; this is partly owing to the diminished sensibility of the gustatory nerve itself, and partly to the diminution of the sense of smell, on the perfection of which depends our appreciation of the more delicate species of sapidity. The surface of the tongue is more rugose than in younger subjects, and there is generally a deficiency of moisture, which is an additional cause of diminished sensation.

* Dict. de Méd. art. *Age*.

The ear, both in its external appendages and in its internal structure, presents certain conditions which very well account for the frequency of deafness among the aged. It is true the cartilages become harder, more elastic, and therefore more vibratory, but the internal surface of the meatus is often thickened, and obstructed by a dense cerumen. The membrana tympani is more rigid and therefore less capable of varying with the degree of the vibrations. In the internal cavity, although the mastoid cells are enlarged as life advances, the deficiency of the liquor cotunnii in the vestibule, the cochlea, and the semicircular canals, must greatly interfere with the production of hearing. In addition to all these circumstances there is probably an idiopathic insensibility of the nerve.

The modifications of the organ of vision are familiar to all who have paid even the most superficial attention to the science of optics. The cornea is less transparent and less convex, partly from the diminution of the aqueous humour, and partly from the condensation of its texture. The latter change is more marked at the circumference, where a nebulosity is often formed, which has gotten the name of gerontotoxon, or arcus senilis. The pigmentum diminishes, and the iris grows paler in conformity with the altered colour of the hair. The crystalline lens is denser, less transparent, and often acquires a yellow tint; the vitreous humour likewise suffers a decrease. The retina is considerably attenuated, but has increased in firmness. The punctum luteum is paler, and not unfrequently altogether effaced; a change which, in the opinion of Meckel,* bears a direct ratio to the diminution of the transparency of the cornea. These several alterations are necessarily followed by two results—diminished refraction of the rays of light, and torpor of the nervous function, both of which produce *presbyopia*. That long sight bears a relation with nervous as well as more mechanical causes is, we think, attested by the fact that this kind of vision is modified by temporary excitement of the brain, as in phrenitis.†

If we now take a retrospect of the revolutions which have occurred in the several structures enumerated, and endeavour to arrange them under specific heads, it will be found that diminution of bulk, deficiency of fluid, and condensation of substance, comprehend them all or nearly all. The attenuation has been generally ascribed to a preponderance of absorption over deposition, or a reverse of that condition in which incremental growth consists. But we cannot enter upon the question here, and must refer to the article Nutrition, contenting ourselves with the remark that it seems a superfluous multiplication of causes to sup-

* Op. cit. t. iii. p. 261.

† See Abercrombie on Diseases of the Brain.

pose that absorption increases, when the cessation or diminution of deposition fully explains the fact, provided the absorption is only maintained in its usual ratio.

Concerning the lessened quantity of fluid we have already made some remarks, and hinted at its relation with impaired digestion and slackened circulation. Here it is sufficient to observe that the fact is a sign of diminished vitality, by which we mean merely a diminution of vital actions, especially of those of nutrition. The abundance of fluid in the young succulent body is adapted to the constant accumulation of new particles, and to the increasing complexity of the organization of the tissues, as well as to the reparation of waste, or to the counteraction of decomposition;—by the still abundant though diminished quantity in the adult the composition is maintained and rendered more exquisite;—in the old man there is only enough required to keep up that degree of renovation, which is necessary to the integrity of the structure, and even this action is less than in former periods, because the organization, from its chemical nature, is less prone to decomposition. This brings us to the consideration of the third general fact, or the condensation of tissue, which will require more particular notice, because great importance has been assigned to it by some writers. The condensation is a result of the deficient humidity just spoken of; but this is not all, otherwise the condensation would be merely that of dryness; the tissue itself is of firmer materials. Thus membrane becomes ligament, ligament cartilage, cartilage bone, and bone increases in its earthy proportions. This hardening of the whole body is spoken of by many writers as the cause of decay, and ultimately of death, by the gradual closure of all the small vessels, and the obstruction to vital motions; while the methods of averting old age, proposed by the same authors, turned chiefly upon an artificial supply of moisture to the body. Galen constantly alludes to this condition when treating of old age, and the means of resisting its tendencies.* Lord Bacon, in his curious and highly interesting treatise, entitled Historia Vitæ et Mortis, has much to say upon desiccation and the methods of preventing it, such as bathing and inunction. The fable of the restitution of old Æsop by the cauldron of Medea, he considers typical of the utility of the warm bath in softening the substance of the body. So much stress does Haller lay on the effect of the universal tendency to induration, that he tells us that one of the reasons why fishes are so long-lived is because their bones are never hardened to the same degree as in the higher animals—"Inter animalia aves longæviores sunt, longævissimi pisces, quibus cor minimum, et lentissimum incrementum, et ossa nunquam indurantur." Primæ Lineæ, § 972. There is, however, we think, but little foundation for the supposition that induration stands in the relation of cause to the general failure of the functions of the body. It is rather a symptom of decline, or one of the phenomena in which decline consists, and is therefore itself the effect of the failure or alteration of some of the functions, more especially of the assimilative. It is a deterioration of interstitial secretion, partly promoted by the changes in circulation, in digestion, and probably in innervation, and partly itself contributing to these changes, but primarily owing its origin, like the latter, to the ultimate law, which determines that at a certain period decay shall transpire. It is in one respect a descent in the scale of organization. This indeed is indicated by the paucity of fluids and by the slow nutritive motions, which conditions are always sufficient to warrant our application of the terms, diminished vitality or less vitalized structure; but the substance itself, independently of these deficiencies of action, belongs to a more simple organization. We examine a bloodvessel, and instead of finding its coats of that complex texture which enables it to accommodate itself by a property, known only in living bodies, similar but superior to elasticity, we mean tonicity, we observe a plate of osseous matter, unyielding, insensible, immobile, possessing no other vital character than bare assimilation or molecular growth. We search for those admirably constructed substances which are interposed between the ribs and the sternum, and by their elasticity give extent and facility to the respiratory movements, and we discover them converted into the same matter as the contiguous bones, with the coarse property of cohesion, and, as in the former instance, with nothing but its growth to redeem it from the character of mere inorganic matter. We untangle the muscle, and instead of the irritable fibre, soft in texture but firm in contraction, we find a torpid substance, scarcely fibrous in form, firm in mere physical cohesion, weak in vital contraction, and consequently of a degraded organization. The processes of induration about the joints, the glands, and the integuments, will all, when examined, be found to approximate more than the former conditions of these parts to the qualities of the inanimate world. Homogeneousness of substance is alone an indication of a low organization, and a body which possesses both this property and hardness, may be considered on the very outskirts of the region of vitality. Such are the properties of osseous deposits. May we not here perceive an analogy with the animals of the inferior classes? In many of the mollusca how trifling a degree of vitality seems adequate to the formation, growth, and reparation of their calcareous coverings and appendages; or to go down to the coralines, madrepores, and porifera, we observe that the very lowest structure that can be considered animal is sufficient to secrete or assimilate those vast collections of earthy matter which pave the ocean, and rise into islands, mountains, and mighty continents. In this hardened constitution, this simplified but degenerate structure, we see that the frame of man, in its natural decay, loses the characters that

* See his treatises De Sanitate Tuendâ, and De Marasmo.

once distinguished it from the dust, and that not less literally than truly it has become more and more "of the earth earthy."

We have now traversed as far and as minutely as our space would allow, the organs and tissues, with their various alterations. It remains for us to inquire whether any one of them may be considered to stand in the relation of cause to the others. We have already dismissed the supposition, that rigidity and concretion are productive of the other alterations, and we also partly entertained the question, when treating of the relations between assimilation, the fluids, and the organs subservient to circulation and digestion. But there are one or two additional points which must be alluded to in this place.

The decay of all the organs, concerned in the *life of relations*, has been shewn to depend on a failure in the actions which are necessary to their generation and maintenance; these organs may, therefore, be dismissed at once from our inquiry into the causation or priority of the processes of degeneration. Yet the observation of the marked declension of the function of the nervous system throughout the body, has led to the hypothesis, that the failure in this power is the ultimate fact in the history of our decline, the fact to which all the others may be traced. This view is suggested by Dr. Roget in his justly-admired article on Age, in the Cyclopædia of Practical Medicine. He considers the general condensation of tissue throughout the system, to be occasioned by a diminished force of circulation, which allows the capillaries to collapse and become obliterated; the weakened circulation this distinguished author is inclined to attribute to a diminution of nervous power in the muscular fibres of the heart; whence he infers that the declension of nervous power bears the priority in the chain of events. We do not feel prepared to adopt the inference; for if we admit this failure in the innervation of the heart, (and whether its fibres are dependent on nerves for their contractility, is still an unsettled question,) are we to pass over the condition of the blood? Might we not say that the enfeebled contractions of the heart are referable to an alteration in the properties of its appropriate stimulus? It is known that this vital fluid has been less affected by respiration than in former periods of our existence; we might therefore, when searching for the earliest antecedent in decay, stop at the imperfect arterialization of the blood. But this would be, in our humble opinion, to pause too soon. The deficient oxygenation of the circulating fluid is sufficiently well known to be the effect of certain changes in the apparatus of respiration. And to what do these changes belong? To a variety of structural, functional, and nervous phenomena, which, if pursued, would lead us into a maze of events, from which it would be impossible to select that which was earliest in its occurrence. Or if we leave the respiratory system, and follow the blood backward to the process of chylification, and ultimately to digestion, we shall, as was shewn above, be equally unsuccessful in obtaining satisfaction. Or finally, if we return to the heart, and investigate the diminished nervous power, admitting this diminution to be alone sufficient for the debility of circulation, is it possible to stop at this phenomenon? Nervous power is nothing but the function of nervous substance, and whether the latter belongs to the ganglionic system, or to the cerebro-spinal, it may have undergone some change, or have been stimulated differently from usual. We know that the sensibility of the nervous system is most intimately connected with the quality of the blood, and with the force of its impulse; so that if it be true that diminished circulation is the effect of diminished innervation, it is no less true that the latter is also the result of the former. Thus it appears that in this inquiry we are constantly arguing in a circle, and it can scarcely be otherwise; the principal structures and functions of the organic life commenced simultaneously; they must decline simultaneously: they assisted one another to grow; they accelerate each other in the way to dissolution. If, however, we are disposed in some measure to qualify this remark, and still hold that there must be some organic changes primary in the work of decay, all analogies must, we think, conduct us to the simple processes of assimilation and secretion, into which all the more complicated functions must be ultimately resolved; but we can go no farther, for we know not what determines or modifies the play of those subtle affinities, motions, and contractions, in which such changes consist.

Some fancy that the enigma is solved by the hypothesis of a diminished vital power; but we have already attempted to show that the interpretation is without value, when applied to the cessation of development; the same reasons render it equally useless as a key to the hieroglyphics of decay. Not less vain were the endeavours of those who could satisfy their philosophy with such a subterfuge of ignorance as was afforded in the theory of a sum of excitability, originally allotted to the system, and gradually exhausted, &c.; as if excitability could possibly mean any thing more than an expression of the collective phenomena of excitement, or vital movement. It is exactly on a par with the doctrine of decreasing vitality.* Some talk prettily and poetically of the vital flame burning out, of oil gradually wasting, of fuel expended,— phrases applicable enough as metaphors, but absurd when propounded, as they too often are, as statements of matters of fact.

When philosophy has failed to discover antecedences, she may still find a prolific source of employment in the study of harmonies. There is no event to be found in the relation of cause to those organic changes which, without the intervention of accidental agents, ultimately affix a bound to the duration of man's existence. As no cause can be elicited for the termination of development, neither can we better explain

* "La gêne de l'influence vitale s'accroit sans cesse."—Cabanis.

why growth does not continue stationary, and maintain the bodily structures for a series of ages, so long as external circumstances remain the same. We live in the midst of agents that both supply us with life and infest us with poison: for a time we resist the baneful tendencies, and then gradually succumb, but in what manner we are at present ignorant. The prevalence of certain functions has been supposed to fortify certain animals against the outward agents or inward processes that would otherwise urge them to dissolution. The influence of respiration upon nutrition is well known, and consequently a large sum of respiration has been alleged to account for the longevity of birds; but there are equal or much greater instances to be found among fishes and reptiles, the amount of whose respiration is extremely small. In the one case the vitality is said to be less rapidly consumed, in the other to be more abundantly supplied; explanations which amount to little more than statements of the same facts in different language. Lord Bacon was of opinion that birds owe their lengthened existence partly to the smallness of their bodies, and partly to their being so well defended by their teguments from the atmosphere; while he accounted for the long life of fishes by the non-occurrence of desiccation in their aqueous element. There is nothing satisfactory to be obtained from speculations of this sort. The most that we can learn is the variation in the term of existence by the influence of various outward agents and modes of life. But whatever variation may be discovered, it will still appear that climate, and time, and custom, and science have never prolonged the date beyond certain limits. The study of these circumstances, and the appliances of art, undoubtedly tend to enable a greater number to attain the extreme goal, but can never give the power of transgressing it. Vain, then, as Boerhaave observes, are the hopes of men who look for an *agerasia!*

Although at present, then, we cannot trace the causes of the bounded nature of our existence, yet it is not difficult to discern its fitness to our constitution, and to the universal frame of things. The brevity of life is an ancient complaint; lamentations have been chaunted over it time out of mind: but its antiquity does not redeem this, any more than many other opinions equally hoary, from the character of a prejudice. Every consideration of the fact in question with reference to the universe must "justify the ways of God to man" in the disposition of this as of every other event. We have only to conceive the circumstance altered, in correspondence to the idle wish of some aspirant to longevity, and we see that every thing else also would require to be changed; that, in short, the beautiful arrangements of the world and of our social relations would be broken. To notice one or two of these: if the life of man were longer than it now is, his progeny would need to be greatly abridged from their present numbers, or they would soon exceed the ratio of subsistence. The time occupied in attaining maturity bears a direct proportion to the period of existence in the mammalia; consequently, if life were prolonged beyond its present limits, that time during which the offspring of man is either helpless or very dependent on the parents, would be also lengthened, and the accidents of disease or other casualties remaining the same, it is clear that confusion, distress, and manifold calamities would accrue to a rising generation. After the attainment of maturity and of its accompanying faculties, it is not clear that any thing would be gained by the possession of these for a longer period than is now allowed; since we know but too well that men, after a time, lose the spirit of enterprise once engendered by the consciousness of increasing or lately-acquired powers, and fall into habits of action which they are unwilling to abandon, but which do not advance the resources of the species beyond a certain limit. Hence the advantage of their giving way to others, to whom they can commit their knowledge, and who, by their unworn energy, will advance it further. "Life is sufficient for all its purposes if well employed," was well observed by Dr. Johnson; and what follower of medicine can forget that the immortal sage of Cos, by the example which he afforded in his well-spent life, disarmed his own antithesis of its woful point: ὁ βίος βραχὺς, ἡ δὲ τέχνη μακρή.

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(J. A. Symonds.)

ALBINO. (Syn. *Albinismus, leucopathia, leucæthiopia*).—This term, as employed in physiology, appears to have been first used by the Portuguese* to designate a peculiar condition of the human body, which was occasionally observed among the negroes in the western parts of Africa. It consists in the skin and the hair being perfectly white, while in the

* Vossius, de Nili origine, cap. 19. p. 69; see also Ludolf, Hist. Æthiop. Com. lib. i. cap. 14. No. 100. p. 197. The name by which the African Albinoes are known among their countrymen is Dondos: by the French they are frequently termed Blafards.

form of the features and in all other respects the individuals in question exactly resemble the negro race. Another striking peculiarity of the Albino is the state of the eye, which is of a delicate pink or rose colour; it is likewise so sensible to light as to be unable to bear the ordinary light of the day, while in the evening, or in a dark shade, its functions appear to be sufficiently perfect. We learn from Wafer, who accompanied Dampier in one of his voyages, and who relates his adventures in crossing the Isthmus of Darien, that Albinoes are not unfrequently found among the inhabitants of this district.* We are also informed by various travellers and naturalists that they are often met with in some of the oriental isles, more especially in Java and Ceylon;† in all these cases exhibiting the peculiar appearance of the skin, hair, and eyes, while, in other respects, they conformed to the external and physical characters of the people among whom they are found. The same circumstance occurs in this country and in the other parts of Europe, although, if we are to place any confidence in the accounts of travellers, the Albino is much more frequently met with in tropical climates, especially in the western parts of Africa, and in Darien, than in the more northern regions.‡

We meet with a few seattered remarks in the writings of the ancients, which render it evident that this peculiar state of the human body had fallen under their notice. We have the following passage in Pliny: "Idem" (Isigonus Nicæensis) "in Albania gigni quosdam glauca oculorum acie, e pueritia statim canos, qui noctu plus quam interdiu cernant."* The same circumstance is referred to by Aulus Gellius: ". . . . in ultima quadam terra, quæ Albania dicitur, gigni homines, qui in pueritia canescunt, et plus cernunt oculis per noctem, quam inter diem;"† and by Solinus: he says that the Albanians "albo crine nascuntur;" "glauco oculis inest pupula, ideo nocte plus quam die cernunt."‡ Pliny, in speaking of the inhabitants of a certain district in the interior of Africa, names them Leucæthiopes;§ and, as it has been supposed that in this passage he referred to the Albinoes, the term has been applied to them by some eminent modern naturalists;|| but it appears more probable that the Leucæthiopes were a tribe of negroes whose complexion was rather less dark than that

* Wafer's New Voyage, p. 134..8; Buffon, Hist. Nat. t. iii. p. 500; Wood's Trans. v. iii. p. 419, 10; Pauw, Recherches sur les Americains, par. 4, sect. 1. t. ii. p. 1 et seq.; Raynal, Hist. des Indes, t. iii. p. 288. The earliest account which we have of the South American Albinoes is by Cortez, in the narrative of his conquest of Mexico, which he transmitted to Charles V. In describing the palace of Montezuma, among other objects of rarity or curiosity which were found in it, he says, "In hujus palatii particula tenebat homines, pueros, fœminasque a nativitate candidos in facie, corpore, capillis, superciliis, et palpebris." De Insulis nuper inventis narrat., p. 30 of "Nar. Sec.;" see also Clayton, in Manch. Mem. v. iii. p. 261 et seq.

† Buffon, t. iii. p. 399 and 415: Wood's Trans. v. iii. p. 328, 9 and 344. We have not been able to procure the "Voyages de Legat," which is referred to by Buffon and others, as containing the original account of the Albinoes, or, as they have been termed, Chacrelos, of Java. With respect to the Bedas of Ceylon, as originally described by Riheyro, Hist. de Ceylon, ch. xxiv., and more lately by Percival, Account of Ceylon, ch. 13, and by Cordiner, Desc. of Ceylon, v. i. c. 4, it seems evident that they are not to be considered as Albinoes. The only remark which Ribeyro makes on their physical character is, "Ils sont blancs comme des Européens, et il y a même des roux parmi eux," p. 178. Percival, who saw some of them, states that their complexions are fairer and more inclined to a copper colour, than those of the other inhabitants; while all that is said by these writers respecting their habits and modes of life indicates that they are a distinct race or tribe. The term Beda, or Badah, appears to be a corruption of Vaddah, or Veddah, which Knox informs us is the name of the aborigines of the island; Account of Ceylon, p. 61; see also Brown, in Brewster's Encyc. art. "Ceylon," p. 704; Cordiner and Percival, ut supra.

‡ Vossius and Ludolph, ubi supra; Argensola, Conquist. de las Islas Malucas, lib. ii. p. 71, speaks of Albinoes as not uncommon in these islands; De la Croix, Rélation de l'Afrique, par. iii. liv. ii. sect. ii. §. 13, "Albinos, hommes blancs, ou Mores blancs," informs us that they compose a considerable body of attendants at the court of the king of Loango; the same statement is made by Ludolf, ubi supra, and by the author of the Hist. Gén. des Voyages, t. vi. p. 250 et seq.: Bowdich, Mission to Ashantee, p. 292, observes, that the king had at his court "nearly one hundred negroes of different colours, through the shades of red and copper to white;" he adds that they were "generally diseased and emaciated;" some of these were probably Albinoes. Cook, in his first voyage, saw six Albinoes in the small population of Otaheite, v. ii. p. 188; in his second voyage he saw one in New Caledonia, v. ii. p. 113, 4; and in his third voyage, he met with three in the Friendly Isles, v. i. p. 381, 2. These, it may be remarked, must have belonged to the Malayan variety. See also Winterbottom, Account of Sierre Leone, v. ii. p. 166 et seq.; Stevenson, in Brewster's Encyclopædia, art. "Complexion," p. 41, 2; Bory St. Vincent, L'Homme, t. ii. §. "Hommes Monstreux," p. 143-7; also in Dict. Class. d'Hist. Nat. art. "Homme," p. 166 et seq.; Renauldin, in Dict. des Scien. Méd. art. "Albino;" Lawrence's Lect. p. 287; Is. St. Hilaire, Anom. de l'Organization, t. i. par. ii. liv. iii. ch. i. p. 296, 314, 5, and art. "Mammifères," in Dict. Class. d'Hist. Nat. p. 113. Some of the earlier writers did not hesitate to affirm, that they were confined to the offspring of negroes, Monge, Journ. Phys. 1782, p. 401 et seq. Suppl. We have no very distinct account of Albinoes among the Chinese and Mongols, but they appear to be as frequent among the Malays and native Americans as among the Æthiopians.

* Hist. Nat. lib. 7. cap. 2. See the note of Cuvier, in his edition of 7th . . 11th books of Pliny, t. i. p. 18.

† Noct. Attic. lib. 9. cap. 4.

‡ Polyhistor, cap. 15. p. 25. See the remarks of Saumaise, Exerc. Plin. p. 134, and of Pauw, t. ii. note in p. 13.

§ Lib. 5. cap. 8. We also find the same term in Pomponius Mela, lib. 1. cap 4, and in Ptolemy, Geog. lib. 4. cap. 6; but it is not accompanied by any description of the people so designated.

|| Among others by Blumenbach, Gen. hum. var. § 78. See Is. St. Hilaire, p. 297, note. We may remark that the term is objectionable, as indicating that the Albino is confined to the Æthiopic variety.

of the Africans generally.* It has been likewise supposed that Celsus alluded to the Albino, when he speaks of a peculiar condition of the skin under the name of Leuce;† but this appears to be a morbid cutaneous affection, and to have no reference to the subject now under consideration.

From the number of Albinoes which were supposed to exist in certain countries, as well as from the marked peculiarity in their appearance, an opinion was long entertained that they formed a distinct race or variety of the human species,‡ originating in some unknown cause, and bearing the same relation to the other inhabitants of the countries in which they are found that the acknowledged varieties of the human species bear to each other. But this opinion, although sanctioned by high authority, may be considered as decisively disproved by the well-ascertained fact, that Albinoes are born of parents who do not possess this characteristic peculiarity of the skin, hair, and eyes.§

Although Albinoes are of comparatively rare occurrence in Europe, yet we have had a sufficient number of examples to render us perfectly familiar with the appearance which they present, and with the precise nature of the circumstances which characterize them.* The skin is of a milky whiteness, without the slightest admixture of the brown or olive tint which is found in the complexion of even the fairest European female; the hair is also perfectly white,† and is generally of a soft or silky texture, while all the coloured parts of the eye are of a delicate rose colour. We are informed that the skin of the African and American Albino is not only completely free from any shade of brown or olive, but that it is also devoid of the pink tinge which is found more or less in the complexion of the European. It would appear, likewise, that the skin of the tropical Albino is frequently in a diseased state, being covered with scales of a leprous nature, and with a serous exudation, which proceeds from the fissures or clefts that take place in various parts of the surface.‡

It has been a very general opinion, that besides the peculiar state of the integuments, the Albino possesses a general delicacy of habit and constitution, and that he exhibits a deficiency even of mental power.§ For this latter opinion there appears to be no sufficient foundation, and with respect to the former we may remark, that any general weakness of the physical frame, if it be actually found to exist, may be probably referred, at least in some degree, to the peculiar condition of the eyes and the skin, which are not well adapted either to a

* See the note of Hardouin in loco, Valpy's ed. p. 1285, Le Maire's, t. ii. p. 438; also the remark of M. Marcus in M. Ajasson's Trans. of Pliny, t. iv. p. 185. It is, perhaps, to this lighter coloured negro, rather than to the proper Albino, that we must refer, in part at least, the accounts which are given by travellers of the great number of white Africans that have been collected in certain situations. We may remark that all accounts of Albinoes that are given in general terms only, should be received with a certain degree of caution, unless the peculiar state of the eye is distinctly noticed. Humboldt remarks that the missionaries, when they met with any Indians that were less black than ordinary, were accustomed to call them white; Pers. Nar. by Williams, v. iii. p. 287 et seq. See Prichard, in Medical Cyclop. Art. "Temperament," p. 163.

† De Medicina, lib. 5. cap. 28. § 19.

‡ This appears to have been the case even with Haller, El. Phys. xvi. 4. 13. p. 492. Voltaire maintains this hypothesis, Essai sur les mœurs, Œuvr. t. xiii. Introd. and p. 7, 8. Buffon inclines to it; but his opinion on this point is not decided or uniform, t. iii. p. 501. See Is. St. Hilaire, p. 295.

§ In addition to the authors already referred to, we have a case of this kind by Helvetius, Hist. Acad. Sc. 1734, p. 15 . . 7. The Albiness described by Buffon was born of black parents: see also Castillon, in Berlin Mem. 1762, p. 99 . . 105; Dicquemare, Journ. Phys. 1777, p. 357 . . 0, and 1788, p. 301 et seq.; Hist. Acad. Scien. 1744, p. 12, 3; and Maupertuis, Ven. Phys. p. 135 et seq.: Jefferson, Notes on Virginia, p. 103 . . 5, mentions an instance of three Albino sisters born of black parents; two of these had black children; Firmin, Descrip. de Surinam, t. i. p. 153, 5; Goldsmith's Anim. Nature, t. i. p. 452, 3; Bruc, Hist. des Voyages, t. iii. p. 370, 0. See on this point Is. St. Hilaire, p. 303. We have a decisive proof that the peculiarity of the Albino is merely accidental and individual, and does not constitute a distinct variety, in the state of the offspring of an Albino and a black negro, which is not intermediate between the two, as in the case of the Mulatto; Hunter, on the Anim. Œcon. p. 248; Is. St. Hilaire, p. 305...7.

* We have a copious list of references in Blumenbach, p. 278 . . 0, in Lawrence, p. 281 . . 9, and in Is. St. Hilaire, ut supra and §. 5. One of the earliest of what may be considered as the correct descriptions is that of Buffon, Supp. t. iv. p. 559 et seq. The descriptions of Blumenbach, §. 78, and of Saussure, Voy. §. 1037 . . . 1043, are particularly correct and characteristic: to this we may add the more recent account of Is. St. Hilaire, t. i. par. 2, liv. 3. ch. 1, §. 2 and 5. We are informed by Ludolf, ubi supra, that the first modern writer who distinctly mentions the Albino is Tellez.

† Blumenbach particularly characterizes the whiteness of the hair of the Albino as being "gilva, colori cremoris lactis quodammodo comparanda," p. 275.

‡ See Vossius, Ludolf, De la Croix, Cook's First Voyage, and Winterbottom, ut supra; Blumenbach, p. 274; Buffon, in Hist. Acad. Scien. 1760, p. 17; St. Hilaire, p. 304, 5: Wafer, in his description of the white inhabitants of Darien, p. 134, et seq., says that there is a white down on their skin.

§ Wafer, p. 134-8; Buffon, t. iii. p. 503; Wood's Trans. vol. iii. p. 420; Voltaire, t. xv. p. 269,70; Pauw, t. ii. p. 9, 10; Raynal, t. iii. p. 288; Dubois on the People of India, ch. xv. p. 199 et seq.; Firmin, t. i. p. 153 . . 5; Dalin, in Amœn. Acad. t. vi. p. 74, note; Isert, Voy. en Guinée, ch. xv. p. 199 et seq.; Labillardière, Voyage, t. ii. p. 141; Winterbottom, ut supra; Rayer, sur le Peau, t. ii. p. 193 . . 203; Blandin, Dict. Méd. Chir. Prac. "Albinie;" Breschet, Dict. de Méd. "Albino;" Sonini, in his edition of Buffon, t. xx. p. 355-6, note. So far as regards the state of the intellect, the charge is repelled by M. Sachs, who gives a minute account of the peculiarity in his own person and that of his sister; Hist. Nat. duor. Leucæthiopum. Jefferson informs us, that the Albinesses, of which he gives an account, were "uncommonly shrewd, quick in their apprehension and reply," p. 103-5.

bright light or to a high temperature, and therefore render the individuals less able to bear exposure to the weather, or to perform the ordinary occupations of life. To the same cause may be ascribed the morbid condition of the skin, which, as was remarked above, occurs not unfrequently in hot climates, and which is not observed in the European Albino. Partly from the circumstances stated above, and partly from the idea of imperfection or defect, which is connected with their appearance, the tropical Albino is generally regarded by his countrymen with a degree of compassion or even of contempt;* and hence is derived one of their popular denominations, chacrelas, which is a corruption of kakkerlakken, the Dutch name for the cock-roach, as being, like those animals, able to leave their haunts only in the evening.†

Besides the complete Albino, which we have now described, there are occasional examples of individuals, where the whiteness of the skin exists in certain parts of the surface only, while the remainder of the body is of its ordinary colour.‡ In the majority of cases the peculiarities which constitute the Albino are connate, and continue during life without any change. There are, however, some instances, where the whiteness of the skin does not exist at birth, but makes its appearance at a subsequent period, generally by slow degrees, until the complete Albino character is induced.§ When once formed it does not seem that it ever disappears, or is even in any degree diminished, nor have we any authentic accounts of its being removed by any constitutional change, either natural or morbid, or by external applications.

* Vossius, p. 68, informs us that they are avoided by the other negroes, as supposed to be diseased. De la Croix says the negroes regard them as monsters, and do not permit them to multiply, ut supra. Dubois, p. 199 et seq. observes that they are named lepers by birth, and that when they die their bodies are not buried or burnt, but cast on dunghills. See also Firmin, ubi supra.

† Blumenbach, p. 277; Lawrence, p. 287; St. Hilaire, p. 296.

‡ Phil. Trans. vol. xix. p. 781, and Lowthorpe's Abridg. vol. iii. p. 8; Buffon, t. iv. p. 565. tab. 2, et p. 571, tab. 3; Arthaud, in Journ. Phys. 1789, pt. 2. p. 277,8; Rush, in Amer. Trans. vol. ii. p. 392 et seq.; Gumilla, El Oron. Ilus. t. i. p. 109 et seq.; Ditto, Hist. de l'Oronoque, trad. t. i. p. 150 et seq.; Jefferson, p. 105; Blumenbach, § 48; Rayer, ut supra; Is. St. Hilaire, p. 309 et seq.; Isert, p. 156. Bell, in Travels in Asiatic Russia, p. 217,8, saw a number of persons with white spots on the skin, but it seems probable that this was the effect of some cutaneous disease. The partial Albino appears to have been noticed by the ancients; Lucian, Prometh, t. i. p. 15.

§ Blumenbach, p. 276, says it is "semper connatus;" see, also, Lawrence, p. 285. There are, however, certain well authenticated cases, where the skin of the negro has gradually changed its colour from black to white; sometimes the change has been general, sometimes only partial; Bates, in Phil. Trans. vol. li. p. 175 et seq.; Gualtier, in Journ. Phys. t. lxx. p. 248 et seq.; Le Cat, sur le Peau, p. 112 et seq.; Rayer, ut supra; Fisher, in Manch. Mem. vol. v. p. 314 et seq.; Rush's Remarks on the same, Amer. Trans. vol. iv. p. 289 et seq. In one of the four cases which are mentioned by Le Cat, the change of colour appears to have been the consequence of a severe burn or scald. Besides the partial Albino, we have what has been termed the imperfect Albino, where the peculiarity exists in a certain degree only; Is. St. Hilaire, §. 4. p. 312 et seq.

Although, as has been stated above, this peculiarity occurs in individuals, who did not derive it from their parents, yet, like all those deviations from the ordinary structure of the body, which have been styled accidental varieties, when once produced, it is disposed to propagate itself by hereditary descent. There are also certain individuals, who have a tendency to produce it; so that even among the few European Albinos, of which we have a minute account, we have cases of its occurrence in two or more members of the same family, either as connected by parental descent, or by collateral relationship.* We have no instance on record of the offspring of a male and female Albino.

The whiteness of the skin and hair, both general and partial, is not confined to the human race; it is found in most, if not in all the species of the mammalia, and in some of these, as in the dog, the horse, and the rabbit, is the subject of daily observation;† in most of them, however, the peculiar state of the eye does not exist. These white varieties, like other analogous cases among the lower animals, when once produced, are strictly hereditary, in which respect they differ somewhat from the human Albino.

Various opinions have been entertained by physiologists respecting the nature of this peculiarity, whether it should be considered as a morbid affection,‡ depending upon a diseased state of the constitution, and also respecting its immediate or efficient cause. The first of these points may be regarded as a verbal controversy, depending altogether upon our definition of morbid action; but we conceive, that according to the ordinary definition of the term, we should not consider it as a disease, but as a connate deviation from the perfect structure of the animal frame, not produced by an external cause, and not removable by a remedial agent. For a correct knowledge of its physical cause, we are indebted, in the first instance, to an ingenious conjecture of Blumenbach's, who accounted for the red colour of the eye, and its extreme sensibility to light, by the absence of the pigmentum nigrum.§

* See particularly Saussure's account of the two boys of Chamouni and Sachs's Narrative; also Blumenbach, p. 276 and 279, note; Firmin and Jefferson ut supra; Pauw, t. ii. p. 25; Bory St. Vincent, L'Homme, p. 144, mentions an Albino of the third generation; Is. St. Hilaire, passim.

† Blumenbach, p. 281, 2; Is. St. Hilaire, p. 297..9.

‡ "Ad cachexias referenda videtur affectio," Blumenbach, p. 274; Is. St. Hilaire, §. 6, supposes that there are two species of Albinism, one the effect of disease, the other a true anomaly; but we conceive that the term is not correctly applied to the former state.

§ Comment. de Oculis Leucæthiopum, et De Gen. Hum. var. §. 78.

This conjecture was shortly after verified by Buzzi of Milan, who took advantage of an opportunity which presented itself, of dissecting the eye of an Albino, in which the pigmentum nigrum could not be detected.* He also examined the structure of the skin, which appeared to be deprived of the rete mucosum, that part of it in which its specific colour is supposed to reside; the hair was also found to be deficient in its central coloured part.† Whether, in these cases, the pigmentum nigrum of the eye and the rete mucosum of the skin are absolutely deficient, or are only deprived of their colouring matter, so as not to be detected by the eye, is a point on which different opinions have been formed by anatomists;‡ perhaps, upon the whole, we may be induced to consider the latter opinion as the most probable.

What are the circumstances in the constitution of the parents which should lead to this peculiarity in their offspring is entirely unknown, nor have any conjectures been formed on the subject which can be considered as even plausible.§ The hypothesis of Buffon, which at one time obtained a considerable degree of credit, that white is, as it were, the primitive colour of nature, which, by various external causes, is changed to brown or black, but which the body has always a tendency to resume under favorable circumstances,‖ is completely without foundation: nor does it appear that we can explain it upon the principle, that domestication and the habits of civilized life have a tendency to produce a lighter shade of the complexion, because we trace no connexion between the supposed cause and the effect, and because the production of the Albino is complete in the first instance, and not brought about by any gradual or progressive alteration.

It appears that we must come to the conclusion, that although the anatomical or physical cause of the peculiarity is ascertained, yet that we are entirely ignorant of its remote cause, or of that train of circumstances which leads to its production.*

* For some remarks "on the colour of the pigment of the eye," and its effect on vision, as applicable to the eye of the Albino, see Hunter, p. 243 . . 253; also Blumenbach, §. 51. "Capillorum cum cute consensus," and §. 53, "Irides oculorum cum capillorum colore consentientes."

† Sachs gives us a minute account of the analysis of the hair of the Albino, compared with Vauquelin's analysis of hair in its ordinary state, from which it appears that no iron could be detected in it.

‡ Blandin, Dict. Méd. Chir. Prat. "Albinée;" Rayer, §. 630.

§ Mansfeldt is disposed to ascribe the production of the Albino state to some shock given to the fœtus, by an impression made upon the mother; it is characterized as a "cessation totale, momentanée d'action cérébrale;" Journ. Compl. t. xv. p. 250 et seq. Is. St. Hilaire essentially adopts this hypothesis, ascribing the peculiar state of the skin to an "arrêt de développement," in consequence of which the colouring matter is not formed at the requisite period, p. 319,0. The idea, that it depends upon something peculiar in the seminal matter of the parent, which was maintained by Herodotus, Thalia, §. 101, and was controverted by Aristotle, Hist. Animal. lib. 3. cap. 22, has been revived by Maupertuis, Diss. 2, and by Pauw, t. i. p. 179, and t. ii. p. 21. Le Cat refers the colour of the negro to a peculiar substance, which he names "Æthiope animal," which he supposes is contained in their fluids, analogous to the black inky matter of the cuttle fish; par. 2. art. 1; the absence of this substance converts the negro into an Albino.

‖ T. iii. p. 502,3.; Wood's trans. t. iii. p. 422. We may remark that this speculation of Buffon's is precisely the reverse of that of Hunter, p. 243 et seq.

* "The following cases have not been referred to in the body of the article; De la Nux, Hist. Acad. Scien. 1744, p. 13; Camelli, Phil. Trans. v. xxv, p. 2268; Duddell on the Eye, Suppl. to, sect. iii. §. 30 et seq.; Percival, Irish Trans. v. iv. p. 97, 8; Hunter, Anim. Œcon. p. 250, 1; Traill, in Nich. Journ. v. xix, with an Add. by the editor; Mansfeldt, Journ. Compl. t. xv; Ansieux, in Journ. Méd. de Corvisart, t. xiv, p. 263, 4.

For the following epitaph, which appears to have been written on an Albino child, we are indebted to a literary friend, the Rev. Jos. Hunter.

"Upon Thomas, son of Ric. Elmhurst by Margaret his wife, daughter to Ric. Micklethwaite: whose promising parts, were interrupted by an early death.

" . . . This boy no Albian was, yet gray hair'd borne
Who saw old age and night as soon as morne.
His grave's a cradle; there his God him lay'd
Betimes to sleep lest he the wanton play'd.
Bid him good night! i'th bed of dust sleep on
Until the morne of Resurrection.

"Anagram.

"Lo Earth misseth me, 1632."

From the Church of Worsborough, Com. York.

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(*J. Bostock.*)

ALBUMEN, (Fr. *Albumine*, Germ. *Eyweisstoff*,) is one of the most important proximate principles of animal bodies; it is the leading ingredient of the blood, of many of the secretions, and of muscular fibre, cartilage, and membrane: the white of egg (whence the generic term *albumen*) presents it in considerable purity, and it is from this source, and from the serum of the blood, that we chiefly obtain it for the purposes of experiment. In this article we shall describe the leading properties of albumen; and in others, refer to its principal modifications.

The white of egg may be regarded as a combination of albumen with water; it contains small quantities of saline substances, which are inseparable in its liquid state. When it is evaporated at a temperature below 120°, it dries into a brittle, shining, transparent substance of a pale yellow colour, inodorous and tasteless. Its ultimate constituents, exclusive of saline matters and a trace of sulphur, are carbon, hydrogen, nitrogen, and oxygen; of these the relative proportions have been determined by Gay Lussac and Thenard, who analysed the white of egg dried at 212°; and by Dr. Prout, who employed the dried serum of slightly inflammatory blood; the following table shows its theoretical composition as contrasted with these experimental results:—

	Atoms.	Equivs.	Theory.	G. Lussac.	Prout.
Carbon..	8	48	51.61	52.883	50.00
Hydrogen	7	7	7.53	7.540	7.78
Nitrogen	1	14	15.05	15.705	15.55
Oxygen	3	24	25.81	23.872	26.67
	1	93	100.00	100.000	100.00

White of egg, when heated to about 150°, *coagulates*, that is, it becomes a white, translucent, and somewhat elastic substance, which, when cautiously dried, shrinks up and assumes the appearance of horn, becoming tough, yellowish, and insoluble in water. Two parts of white of egg and one of water entirely coagulate when duly heated; equal parts remain, under the same circumstances, semi-fluid; a mixture of one part of white of egg and ten of water becomes opaque, but is not coagulated; and a milkiness is perceptible when the albumen only forms a thousandth part of the solution.* Fresh-laid eggs, and those which have been oiled upon the surface do not perfectly coagulate when put into boiling water, in consequence, probably, of the dilute state of the albumen. One hundred parts of the fresh albumen of the egg, when carefully evaporated in vacuo, leave a residue = fifteen parts. One hundred parts of the coagulated white of a duck's egg (dried in vacuo with sulphuric acid) leave 13.65 parts, which, steeped in water, acquires its original appearance, but in four days only took up 68 of water, though it had lost 86.35.†

When albumen is made part of the voltaic circuit, it presents appearances dependent upon the power used, which, when considerable, excites so much heat as to coagulate it; but with a feeble power and the poles sufficiently distant, coagulation ensues most plentifully at the negative platinum wire; a coagulum also forms at the positive wire, where acid is also sparingly evolved. These phenomena are much interfered with by the evolution of gaseous matters at the respective poles, which occasion a froth, and the appearance of more extensive coagulation than actually occurs.

When coagulated white of egg is boiled for several hours, it shrinks up and becomes hardened, communicating traces of animal matter to the water. Heated by high pressure steam in a copper digester to 400°, it blackens the interior of the vessel, and dissolves, leaving a small residue of unaltered albumen. The solution is brown, and has the odour of boiled meat (from osmazome?). This action deserves further investigation.‡

White of egg soon runs into putrefaction, and evolves sulphuretted hydrogen. The serum of blood kept for two years in a well-stopped phial, blackened its interior, and became a stinking, pale, yellow liquid, still coagulable by heat, and containing hydro-sulphate, carbonate, and acetate of ammonia, and a fetid volatile matter: a portion of yellowish white purulent-looking matter, containing undecomposed albumen, remained at the bottom of the phial. Coagulated white of egg, even under water, long resists putrefaction.

* Bostock, Nicholson's Journal, vol. xiv. and Medico-Chirurgical Transactions, vol. i. and ii.

† Chevreul, Mém. du Museum vii. 180. Ann. de Ch. et Ph. xix. 46.

‡ Gmelin, Handbuch der Theoretischen Chemie, ii. 1053. 3rd ed. Frankfort, 1827.

One hundred parts of dried white of egg, subjected to destructive distillation, yielded carbonic acid, carburetted and sulphuretted hydrogen, prussic acid, carbonate of ammonia partly in solution and partly sublimed, stinking volatile oil, and 14.9 of spongy difficultly combustible carbon, which, by incineration, left 2.21 of ash composed of carbonate of soda, phosphate of soda, and phosphate of lime, (Hatchett.)

Nitric acid, dropped into a solution of albumen, forms a white, flaky precipitate, which is more or less abundant according to the state of dilution of the solution, and which is soluble in ammonia and potash. When coagulated white of egg is kept for some weeks in very dilute nitric acid, it acquires a yellow colour, and if digested in boiling water it dissolves, and has acquired the properties of gelatine, and is precipitated by tan and muriate of tin. Hatchett.)* Cold nitric acid sp. gr. 1.25, gradually tinges coagulable white of egg of a yellow colour, dissolving a little of it, and forming malic acid, with the evolution of nitrogen; its surface becomes tallowy, and in twenty-four hours it falls into a pale yellow powder, which is acid and composed of nitric, nitrous, and malic acids with albumen; when thoroughly washed with water, it becomes more neutral and of an orange colour, still reddening litmus, and remaining insoluble in water, but soluble in caustic potash.† When coagulated white of egg is digested in hot nitric acid, nitrogen, nitrous gas, carbonic acid, and prussic acid are formed, and a dark yellow solution obtained, which is precipitated by the addition of water and ammonia, and which contains malic and oxalic acids, bitter matter, and fat. (Hatchett.)‡

Sulphuric acid is a less powerful precipitant of albumen than nitric acid. Dilute sulphuric acid dropped into an aqueous solution of albumen occasions a precipitate which is soluble in excess of acid; ferrocyanate of potassa throws it down. When coagulated albumen is digested in sulphuric acid, very slightly diluted, it yields a deep crimson solution.§ Coagulated serum digested in sulphuric acid diluted with six parts of water, converts it into acid *sulphate of albumen*, which, when edulcorated with cold water, becomes more neutral, and is soluble in warm water, forming a gelatinous solution, which is precipitated by sulphuric, muriatic, and nitric acids, and by the alkalies. (Berzelius.)|| Coagulated white of egg digested in hot sulphuric acid becomes carbonized without forming artificial tan. (Hatchett.)

When a solution of recently fused phosphoric acid (pyro-phosphoric acid) is added to solution of albumen, it occasions an abundant precipitate: the acid gradually loses this property, and again acquires it by fusion and ignition. (Berzelius.)

Muriatic acid occasions a precipitate in albuminous solutions, and entirely throws down the albumen when aided by heat; but the precipitate is soluble in excess of acid, and in ammonia and potassa. A muriated albumen may be formed in the same way as the sulphate. (Berzelius.) Coagulated egg-albumen digested in muriatic acid gradually acquires a purple colour. (Hatchett.) Albumen which has been precipitated by muriatic acid, often becomes reddish when collected and exposed upon a filter.

When coagulated seralbumen is digested in acetic acid, it becomes soft and transparent, and, aided by a gentle heat, dissolves with the evolution of a little nitrogen. This solution is precipitated by the alkalies, but a slight excess again renders it clear: it is also precipitated by sulphuric, nitric, and muriatic acids, and by ferrocyanate of potassa. When this acetic solution of albumen is evaporated, it leaves a transparent sour residue, soluble in warm water acidulated by acetic acid. (Berzelius.)

Albumen is slowly soluble in liquid ammonia. In solution of potassa it becomes gelatinous, and yields a pale yellow green solution, precipitable by acids and alcohol, and by acetic acid. Heated in liquid potassa, albumen evolves ammonia.

Alcohol and ether coagulate ovalbumen, but pure ether (free from alcohol) does not coagulate seralbumen. (Gmelin.) When serum is shaken with ether, it soon separates upon the surface, holding fatty matter in solution. (Gmelin.) Coagulated serum digested in alcohol or ether yields a solution of fatty matter.

Coagulated ovalbumen, when long boiled in water, becomes bulky and falls into pieces, and a small portion is dissolved: the filtered solution, evaporated at 212°, leaves a pale brown film, and is alkaline; it is rendered turbid by mineral acids, acetic acid, and tincture of galls, and by many metallic salts.

When albumen which has been cautiously dried at a low temperature (without coagulation) is triturated with four parts of water, it yields a solution resembling fresh albumen.

A solution of the white of an egg in a pint of water occasions no precipitate in lime, barytic or strontia water, nor in solution of sulphate of lime. Some of the neutral salts render it more or less turbid, and it is copiously precipitated by solution of alum. Nitrate, acetate, and subacetate of lead are precipitated by albuminous solutions. One part of fresh ovalbumen in 2000 of water, or one of dried albumen in 10,000 of water is rendered turbid by subacetate of lead. A four-hundredth part of liquid, or a two thousandth of solid albumen is precipitable by corrosive sublimate. (Bostock.) The precipitate is blackened by potassa, and is probably a compound of muriate of albu-

* Phil. Trans. 1799.

† Berzelius Lehrbuch der Thier. Chemie, p. 38. Wöhler's Translation. Dresden, 1831.

‡ Phil. Trans. 1799.

§ According to Raspail, when sugar is previously dissolved in the sulphuric acid, the albumen is coloured purple, which is deeper in proportion as the acid and sugar are in greater quantity.

|| Lehrbuch der Thier. Chemie.

men and calomel. Nitrate of silver, muriate of gold, and of platinum, also precipitate albuminous solutions. These precipitates are mostly triple compounds of acid, albumen, and oxide, and several of them are redissoluble in excess of liquid albumen.

Albumen is precipitated by tannin in the form of a yellow viscid combination. Water, holding a thousandth part of solid or a two-hundredth of liquid ovalbumen, becomes turbid after some hours by the addition of a solution of galls containing 2.5 per cent. of solid matter. (Bostock.)

The above are the principal chemical properties of liquid and solid albumen as obtained from the egg and from serum of blood; several of their modifications will be noticed under other heads, such as FIBRINE, MILK, BILE, &c.

The cause of the coagulation of albumen is, in many cases, obscure and even inexplicable. It appears possible that the acids by which it is coagulated enter into combination with it so as to form insoluble compounds; the same change probably happens with certain metallic salts, and with tan; its coagulation by alcohol has been ascribed to the abstraction of water. Having remarked the copious coagulation of albumen at the electro-negative pole in the voltaic circuit, I was induced to ascribe the fluidity of albumen to combined soda, the evolution of which seemed to cause its solidification, and it appeared possible that the acids and even alcohol might also occasion coagulation by the abstraction of soda; and that its more enigmatical coagulation by heat only, might be ascribed to the transfer of soda from the albumen to the water. It has been objected to this statement that the addition of alcali to coagulated albumen does not reproduce liquid albumen, and that acetic acid causes no coagulation; but when albumen is once coagulated, its properties are essentially modified, and acetic acid, or even acetate of soda appear to form soluble compounds with it. (Gmelin.) Dr. Turner* supposes that albumen combines directly with water at the moment of being secreted, at a time when its particles are in a state of minute division; but as its affinity for that liquid is very feeble, the compound is decomposed by slight causes, and the albumen thereby rendered quite insoluble. The organization of albumen may certainly be concerned in its singular properties with respect to many coagulants: there are several albuminous fluids, which we shall hereafter refer to, which contain globules resembling those of the blood. In the voltaic coagulation of albumen, that which separates at the positive pole contains globules, which, under the microscope, resemble the blood-globules deprived of their colouring matter.†

The readiest tests of the presence of albumen in fluids are its coagulation by heat, alcohol, and acids; when it is too dilute for such detection, it may be subjected to voltaic electricity, or tested by corrosive sublimate, or by ferrocyanate of potassa; the alcali should, in the latter case, be previously neutralized by acetic acid. It would appear, from Orfila's experiments, that white of egg is an antidote to the effects of corrosive sublimate when taken into the stomach, and that, if administered in sufficient quantity immediately after the reception of the poison, it prevents the progress of the symptoms. The white of one egg appeared sufficient to render four grains of the poison ineffective.

The readiness with which some metallic oxides are received into the system may perhaps be ascribed to their affinity for albumen, with which some of them form compounds not easily decomposable, and in which the metallic oxide cannot be detected by the usual tests, till they have been subjected to heat sufficient to decompose the organic matter. Mercury and silver are thus, in certain cases, detected in the secretions and excretions.

(W. T. Brande.)

AMPHIBIA.—(Αμφις, utrinque, βιος, vita. Fr. *Amphibies.* Germ. *Amphibien.* Ital. *Amphibie.)* A class of vertebrated animals, hitherto almost universally considered as an order of REPTILIA, constituting the *Batrachia* of the later erpetologists. To the retention of the latter appellation, as derived from the Greek name of a single form of the group, and as bearing no reference to any character either of structure or of habit, there is an obvious objection. The term *Amphibia* is therefore here adopted, as designating one of the most striking peculiarities of the class; namely, the change which takes place at an epoch of their life, more or less advanced, from an aquatic respiration by branchiæ to an atmospheric respiration by true lungs, and an equivalent and consequent alteration in their general structure and mode of life.

The *Amphibia* may be characterized as "vertebrated animals, with cold blood, naked skin, oviparous reproduction, and most of them undergoing a metamorphosis or change of condition, having relation to a transition from an aquatic to an atmospheric medium of respiration."

These characters, by many of which the amphibia are distinguished from the reptilia, are sufficiently determinate and important to justify our considering them as a distinct class, according to the generally received principles of zoological arrangement; notwithstanding most even of the modern writers on the subject have retained them as merely an order of reptilia. But it will also be seen that if in the adult state they approach the reptilia in many points of their general structure, their organization, during the early and imperfect condition of the tadpole, partakes no less of that of fishes. As an osculant or intermediate form, connecting two others of higher typical importance, it may be, certainly of greater extent, and consisting

* Elements of Chemistry, 4th ed. 868.

† Prevost et Dumas, Ann. de Chimie et Physique xxiii. 52.

of groups having more striking distinctive characters, there is not, perhaps, a more interesting and satisfactory instance in the whole range of the animal creation than is afforded us in the class of amphibia: a circumstance which can only be fully appreciated by following out the structure of each system of organs, first as it exists temporarily in the tadpole, and ultimately in its permanent condition in the perfect animal.

The class has been variously divided into groups according to the different views of the naturalists by whom they have been arranged. The division adopted by many zoologists of the present day, according to the mere presence or absence of the tail in the perfect state, is not only liable to the objections which belong to all merely dichotomous arrangements, but appears to be far less natural and less consistent with the physiological characters of the groups than that which may be derived from the absence or presence and the duration of the branchiæ. Thus the frogs and toads, which in the adult state have not the vestige of a tail, and the salamanders and tritons, which retain that organ through life, all agree in the early possession of branchiæ, which are subsequently lost and replaced by true lungs, and in undergoing consequently a total change in the medium of their respiration; whilst the proteus and the siren retain their branchiæ, with lungs, (rudimentary at least,) and probably throughout life possess synchronously the twofold function of aquatic and atmospheric respiration. The *amphiuma* and *menopoma* have not as yet been observed to possess branchiæ at any period of their existence, though further observations are necessary to warrant the conclusion of an absolute non-existence of a metamorphosis in these genera.

It appears to me that no one arrangement hitherto given sufficiently distinguishes the different forms; and I venture to propose the following modifications as more consistent with the diversities of structure in the different groups.

Class Amphibia.

Order 1.—Amphipneurta.

Body elongate, formed for swimming. Feet either four, or two anterior only. Tail compressed, persistent. Respiration aquatic by means of branchiæ, throughout life, co-existing with rudimentary lungs. Branchiæ external, persistent. Eyes with palpebræ.

Genera, *Proteus*, *Siredon*, *Menobranchus*, *Siren*, *Pseudobranchus*.

Order 2.—Anoura.

Body short and broad. Feet during the tadpole state wanting; afterwards four, the hinder ones long and formed for leaping. Tail before the metamorphosis, long, compressed; afterwards totally wanting. Ribs wanting. Vertebræ few and anchylosed. Tympanum open. Respiration at first aquatic by branchiæ; afterwards atmospheric by lungs. Branchiæ at first external, but withdrawn within the chest before the metamorphosis. Impregnation effected externally during the passage of the ova.

Genera, *Rana*, *Hyla*, *Ceratophrys*, *Bufo*, *Rhinella*, *Otilopha*, *Ductylethra*, *Bombinator*, *Breviceps*.

Order 3.—Urodela.

Body long, slender. Feet always four. Tail long, persistent. Ribs very short. Respiration at first aquatic by external branchiæ, afterwards atmospheric by cellular lungs. Vertebræ numerous and moveable. Tympanum concealed. Impregnation internal.

Genera, *Salamandrina*, *Salamandra*, *Molge*.

Order 4.—Abranchia.

Body long, formed for swimming. Feet four. Cranium solid. Tail compressed. Respiration by means of lungs only: branchiæ none. No metamorphosis known.

Genera, *Menopoma*, *Amphiuma*.

Order 5.—Apoda.

Body elongate, slender, anguiform. Feet none. Tail very short, almost wanting. Lungs one larger than the other. (The existence of branchiæ at any period of life unknown.) Ribs very short. Sternum wanting. Ears concealed. Impregnation unknown, probably internal.

Genus, *Cæcilia*.

I. *Osteology.*—The changes which take place in the habits and formation of these animals, in their passage from the tadpole or pisciform state to their adult and permanent condition, are not confined to any one system of organs or of functions. The skeleton, the organs of motion, of sensation, and of digestion are not less the subject of these changes than those of respiration and circulation: it will, therefore, be necessary, in treating of each system of organs, to describe not merely their structure in the perfect state, but the less advanced grade of organization from which they emerge in passing from the condition of a fish to that of a reptile.

In the adult state, however, they are found to vary considerably in the form and composition of the skeleton, according to their habits, and to the existence or absence of a tail. The principle of compensation, or, in other words, the extreme developement of one set of organs at the expense of another, which is so often seen to take place in every form of animals, is here strikingly illustrated. In the frogs, whose movements on land, from their feeding chiefly on terrestrial prey, are necessarily extensive, we find the hinder legs developed to an extraordinary degree, for the purpose of enabling them to take enormous leaps, by which they not only seek or pursue their prey at a distance from the water, but rapidly escape from danger, and rapidly regain their place of refuge in the nearest pond or rivulet. As it is evident that a long tail and a generally elongated body, with a flexible spine, would be not only useless but inconsistent with these habits, we find these animals absolutely tailless, the body contracted longitudinally into as short a space as possible, the vertebræ very few, and anchylosed or soldered together into a single immoveable piece, and wholly devoid of ribs.

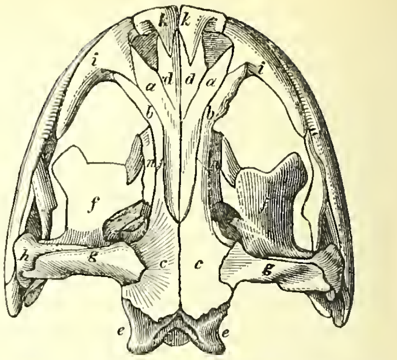
On comparing with this formation, on the other hand, the extensive developement of the tail, the long flexible body, and gracile form of the newts or aquatic salamanders, and reflecting upon the obvious object of this structure in facilitating their motions in the water, we should hardly be prepared to find that the extraordinary extension of the hinder extremities in the frogs, the *primary* object of which is to afford the great powers of leaping just alluded to, is made subservient also to their aquatic life, by enabling them to swim with great facility, aided by a web of skin extending between the toes of the hinder feet.

Now as we shall hereafter see, when treating on the respiration of these animals, that the occasional presence of water, and its application to the surface of the skin, is equally essential to the well-being of both these forms, it is very interesting to observe how admirably this peculiarity in the general requirements is provided for by the very different, and even opposite, construction of their form and limbs, which their individual habits of life demand.

But to return to the detailed anatomy of the skeleton. On examining the general texture of the bones in this class, there is an obvious advance towards the firm calcareous substance of those of the higher forms of vertebrated animals when compared with the bones of fishes, they being more compact, and less transparent and flexible than in the latter animals. The cranial bones, though they retain to a certain extent the character of those of fishes, in the permanent disunion of the different centres of ossification, at least in many instances, yet they do not overlap each other, as in that class, but, on the contrary, remain with their margins at least in contact, and in many cases actually united, though not by true sutures. The elements of which the cranium is essentially composed, and which in a higher grade of organization are found consolidated, are here still exhibited as distinct pieces; a state of things which is strikingly imitated in the progress of the development of these parts in the highest classes during their growth. It is also to be observed that the bones of the face are more closely united to those of the cranium and to each other in the higher than in the lower forms of the class, exhibiting distinct and obvious links in the development of these parts, which we see so beautifully and gradually perfected in the ascending series from fishes up to man.

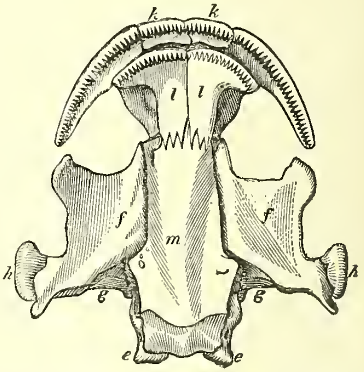
The following enumeration of the separate cranial bones of the amphibia, as existing in the *menopoma alleganiensis*, the gigantic salamander of America, will illustrate the general relations of the distinct centres of ossification, here remaining permanently detached.

Fig. 14.



In figs. 14 and 15 the different elements are thus designated:—*a.* the frontal; *b.* the exterior frontal; *c.* the parietal; *d.* the nasal;

Fig. 15.



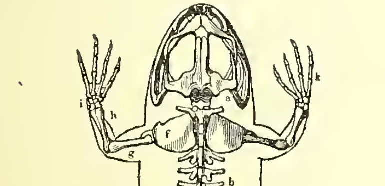
e. the occipital; *f.* the pterygoid; *g.* the tympanic; *h.* the jugal; *i.* the superior maxillary; *k.* the intermaxillary; *l.* the vomer; *m.* the sphenoid; *n.* corresponding to the orbitary processes or alæ of the sphenoid. In the frog and most others the palatine bones are distinct. We here find that the separate portions or elements which in this class are permanently detached, correspond almost exactly with the number found in the cranium of fishes.

It will be observed by a reference to the figures, that the intermaxillary bones—and this is more or less the case in all the amphibia—are much developed transversely, as in the fishes, an affinity which has been already so much insisted on, and which is borne out by the condition of all the other parts of the cranium. The lateral extension of the upper and lower maxillary bones, for instance, as well as of the tympanic and jugal, expands the general form of the skull, without involving any expansion of the cavity of the cranium, which is restricted to a small, central, elongated space. The latter bones also terminate in a condyle, which is received into a shallow glenoid cavity of the lower jaw, a peculiarity which offers a still further illustration of the proximity of this class to the fishes. The lower jaw consists of three distinct pieces on each side, an anterior, a lateral, and a posterior or articular portion. The anterior bone supports the teeth in those genera which have teeth in the lower jaw, and unites with its fellow at the symphysis. In frogs the lower jaw is devoid of teeth, but they are found in the upper jaw, bordering the intermaxillary and the maxillary bones; and the vomers are also furnished, each with a transverse row of teeth; but in the salamander, the menopoma, the proteus, and others, they are found occupying the margin of the lower jaw. In the toads there are no teeth in the lower jaw, but the edge of the jaw-bone is serrated. The second bone of the inferior maxilla occupies the side, and is larger even than the former. It has at the posterior part a coronoid process, behind and within which is placed the third bone, which forms the medium of articulation with the cranium.

It is to the *os hyoïdes* that the principal interest attaches in the present class, as it is that bone which undergoes the most remarkable changes in its form and relations during their transformation, passing from the office of supporting the branchial organs into a true os hyoïdes, and thus offering, as Cuvier has beautifully shewn, an elucidation of the true nature of this apparatus in fishes. As this bone, however, has a direct relation with the respiratory functions, I shall explain these changes while treating on that part of the subject.

The spinal column varies exceedingly in the different forms of the amphibia. In the highest form the vertebræ are fewer than are found in any other animals. In the common frog

Fig. 16.



there are but nine, and in the pipa only eight. Of the nine vertebræ in the frog, the first, the atlas, *a*, has no transverse processes; there are two articular surfaces situated anteriorly, by which it is articulated to the two occipital condyles. In the seven following vertebræ the anterior articular surfaces of the bodies are concave, and the posterior convex. This convex tubercle, which enters the concavity of the next vertebra, consists of the intervertebral cartilage converted into bone. In the tadpole condition of the animal (and this remains permanently the case in the perenni-branchial forms, as the *menobranchus*, the *proteus*, &c.) this intervertebral substance retains the soft consistence which characterises it in fishes; and, as in that class, it is contained in the circumscribed cavity formed by the cup-like hollows of the two articular surfaces of contiguous vertebræ. The elongated fish-like form of those amphibia which retain their branchiæ throughout life, requires that this structure should also be permanent; and we have thus another beautiful example of that perfect chain of organisation which is manifested by this class of animals, from the fish upwards to the reptilia.

The vertebræ of the adult frog have long transverse processes (*fig.* 16, *b*), but are wholly destitute of ribs—a class of bones which would be utterly useless in the particular modes of locomotion to which these animals are restricted, and the absence of which implies a peculiarity in the act of respiration, which will be described hereafter. The spinous processes are very short; the articular are oblique, the posterior of each being placed above the anterior of the following one.

The last or sacral vertebra has large transverse processes (*fig.* 16, *c*) directed a little backwards, to which the ilia (*fig.* 16, *d*) are attached; and to the body of this vertebra is united by two tubercles, a long single bone, extending backwards to above the anus. This bone (*fig.* 16, *e*) is considered by Cuvier as a second sacral vertebra; but by Schultze, Altena, Dr. Grant, and others, it is regarded as the coccyx. The vertebral canal occupies the anterior third of a carina or crest, which runs along the upper surface of this bone, diminishing gradually in its course until it wholly disappears.

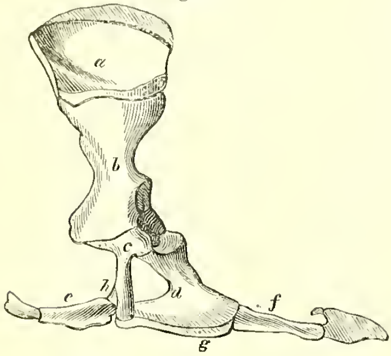
The spinal column in the other orders of the class differs in a remarkable degree from that which has been just described. In the salamander there are thirteen dorsal, two sacral, and about twenty-five caudal vertebræ, which in the genus molge or newt are increased to upwards of thirty. In these the anterior surface of the body is convex, and the posterior concave, a contrary arrangement to that which occurs in frog. The transverse processes are directed a little backwards, each, excepting the atlas, supporting a small rib, which is scarcely curved. The *menopoma* has a similar arrangement. In the *siren* are found forty-three vertebræ in the trunk, and forty-four or more in the tail. They all retain in a great measure the form of those of fishes and of the tadpole of the higher orders of this class, particularly in the existence of the intervertebral cavity or double cone, formed by the apposition of two hollowed surfaces of their bodies, and filled by a semi-cartilaginous mass or intervertebral substance. Eight only of the vertebræ, commencing with the second, bear ribs, which are extremely small, and in fact merely rudimentary. In the tail the transverse processes are only found on a few of the most anterior vertebræ.

The spine of the proteus is not sufficiently different from that of the siren to require any particular description.

The construction of the members, both anterior and posterior, especially the latter, will be found to be arranged on very different plans, according to the habits and requirements of the different groups, and particularly their mode of progression. In the *apoda*, as the *cæcilia*, there are not even the rudiments of limbs. In the other orders they exist under very different degrees of development, according as they are constructed for leaping and swimming, as in the frogs, toads, &c., or for creeping, as in the salamanders; or they are rudimentary, and without any very apparent use, as in the *amphiuma*. It will be necessary to give a cursory description of these forms.

Of the anterior extremity in the anoura.—The shoulder of the frog (*fig.* 16, *f.* *fig.* 17.) consists of the scapula, the clavicle, and the coracoid bone, which all combine to form the glenoid cavity for the head of the humerus. The scapula is composed of two very distinct portions. The upper, (*fig.* 17, *a*,) which is

Fig. 17.



permanently cartilaginous, at least at its margin, is articulated moveably to the inferior and more solidly ossified piece, (*fig.* 17, *b*,) at the inferior and posterior part of which is the articular surface forming its portion of the glenoid cavity, immediately anterior to which it is attached to the clavicle. (*fig.* 17, *c*.) This bone is slender and straight, and is connected beneath with its fellow in the median line. The coracoid bone (*fig.* 17, *d*) is considerably larger than the clavicle, and is also connected with its fellow by its broad median margin. The sternum consists of several pieces, extending from before the clavicles to some distance behind the coracoid bones; the latter terminates in a broad xiphoid cartilage. These parts differ considerably in their relative proportions in different genera.

The arm is developed in a very inferior degree compared with the hinder extremity. The humerus (*fig.* 17, *g*) is short and thick, having a rounded head, received into the glenoid cavity of the shoulder-joint. The opposite extremity forms an almost globular surface for its articulation with the bone of the fore-arm, which is still shorter, and consists of the radius and ulna united, (*fig.* 17, *h*,) having only a slight groove to show their line of union. The carpal bones (*fig.* 16, *i*) are six in number, supporting the four metacarpal bones, (*fig.* 16, *k*.) The index and middle finger have each two phalanges, the others three. The index is particularly large in the male. The thumb is merely rudimentary.

The posterior extremity is greatly developed in the frogs, for the purpose before mentioned, of enabling them to take long leaps, and to swim with great rapidity and energy. The pelvis consists of the three essential bones of this part, the ilium, ischium, and pubis on each side. The iliac bones, (*fig.* 16, *d*,) diverging above, are moveably articulated with the sacrum. They then extend backwards, and form, together with the small ischiatic and pubic bones, (*fig.* 16, *l*,) the cotyloid cavities for the reception of the femur. This bone (*fig.* 16, *m*) is nearly twice as long as the humerus, cylindrical, and having a slight double curve. The leg consists, like the fore-arm, of but one bone, the tibia and fibula being anchylosed through their whole length. This bone (*fig.* 16, *n*) is even a little longer than the femur. It is succeeded by two bones of considerable length, (*fig.* 16, *o*,) having very much the aspect of a tibia and fibula, but which must be considered as bones of the tarsus greatly modified, and are most probably the *os calcis* and the *astragalus*. Between these elongated bones and the metatarsal are four small tarsal bones. The metatarsal bones (*fig.* 16, *p*) are much elongated, as are also the phalanges, (*fig.* 16, *q*,) for the purpose of forming strong oars or paddles with the intervention of a broad web of integument. The inner toe is considerably developed, and the whole structure of the foot and leg thus combines to furnish a powerful and efficient organ of progression.

The elongated forms of the aquatic salamander, the proteus, the siren, &c., in which the vertebræ are developed to so great an extent, present the opposite extreme in the structure of their limbs. These are small, feeble, and appear as it were abortions. In the genus triton and in the salamandra, which possess both anterior and posterior extremities, they differ but little in their general form and development. The bones of the fore-arm as well as of the leg, instead of being respectively anchylosed into a single piece, as in the frogs, are permanently separate, consisting of a distinct ulna and radius in the former, and an equally distinct tibia and fibula in the latter. The toes are four, both before and behind; they are short, slender, and of slight construction.

This imperfect development of the extremities is, however, as we have seen, admirably compensated by the extraordinary extent of the spine both in the body and the tail; and while the limbs afford but very imperfect means of progression on land, the structure of the spine is admirably adapted to the purpose of swimming, which is performed either by a succession of curves, as in the amphiuma and the siren, or by the alternate flexure of the tail, as in the *tritons* and the *menobranchus*.

Having given this general sketch of the osteology of the amphibia in the adult state, it will be interesting to examine the structure of the skeleton in the tadpole. It has already been observed that in this early condition of its existence the animal resembles fishes in all the most remarkable characters of its organization. We find accordingly that the limbs, which are at first scarcely perceptible by the most minute examination, become gradually developed, passing through a rudimentary form beneath the integuments, from which they do not emerge until they have acquired considerable size and a very defined figure. The hinder legs are first seen, and are early employed as a feeble assistance to the more effective tail, as instruments of progression. The tail is developed, however, to a great degree, occupying the same relative size and situation as it is found to do in fishes. The coccygeal vertebræ are numerous, forming a long column, not ossified, but retaining its cartilaginous structure, at least in those forms in which it is deciduous; but in the *salamanders*, the *tritons*, the *proteus*, and all others of the *urodela*, it becomes ossified instead of being absorbed. In the frog and other anoura, as the permanent organs of progression acquire their full development, the tail is slowly removed by interstitial absorption, not suddenly falling off as some have supposed, but becoming gradually smaller and smaller until it wholly disappears. The cranium undergoes no other important change than that of the gradual ossification and expansion of its different elements, the centres of ossification being at first wholly disunited as in fishes, and afterwards assuming the more consolidated structure and closer approximation to each other, by which they approach the reptilia.

II. *Muscular system.*—The similarity which has been already shewn to exist in the osseous system of fishes and of the tadpole and perennibranchiate amphibia, would naturally lead to the conclusion that a corresponding affinity would be found in the muscular apparatus. The muscles which are employed for progression in those early forms of vertebrated beings, are found to consist of oblique layers, abutting upon a median line, and extending along the whole length of the tail on each side. A similar general direction obtains in the muscles both of the trunk and tail in the long-bodied forms of the permanently tailed amphibia. The direction of their action therefore is horizontal, and their progression is effected by the alternate action of the muscles on each side These oblique caudal muscles in the tadpole of the tailless tribe, become absorbed with the vertebræ to which they are attached, as the animal gradually assumes its permanent form; but its aquatic habits are still provided for by the extraordinary magnitude of the flexors and extensors of the thigh, leg, and foot, which are in perfect accordance with the great length of the bones of this extremity, which has been described. The muscles which form this important apparatus of motion are exactly analogous to those which are so peculiarly developed in the human leg. Thus the large glutei extend the femur, the rectus and triceps extend the leg, and by their united and sudden action forcibly throw the whole limb into a straight position, whilst the gastrocnemii, which are here as in the human subject of sufficient size to form a considerable calf of the leg, enable the foot with the wide expanse of its toes, connected as they are by a tense web, to strike with great force and effect the resisting medium in which they live, assisted by the flexors of the toes, which are called into action at the same instant. The same beautiful mechanism is no less adapted for the peculiar nature of their progression on land; by it they are enabled to take those long and vigorous leaps which particularly characterize some of the genera of the acaudate family of this class. It is obvious that the same sets of muscles must be developed for the performance of the energetic and sudden movements abovementioned as are required to sustain the upright form of the human subject in its erect position, those, namely, which extend at once the thigh upon the pelvis, the leg upon the thigh, and the heel upon the leg; and hence arises the remarkable similarity in the conformation of the leg in these otherwise remote forms, and hence too the act of swimming in man must be a tolerably accurate imitation of the same effort as exhibited by the frog.

III. *Organs of digestion.*—The foregoing consideration of the various structures of the organs appertaining to locomotion would prepare us for corresponding differences in those belonging to this important office. These variations, however, are not found exactly to follow those which have been described in the former class of organs. The tadpole condition of the higher amphibia does not correspond in the nature of its food, nor consequently in the structure of the alimentary canal, with the class of fishes, nor indeed with that permanent tadpole, as it may be called, the larviform axoloth.

The teeth, as has been already stated, vary in the different genera not so much in their size and form as in their situation. Thus the whole of the amphibia have teeth in the palate; the salamanders have them also in both the upper and lower jaws, the frogs in the upper only, and the toads in neither. In the two latter genera the palatine teeth are placed in a transverse line, interrupted in the middle. In the salamanders they form two parallel lines, containing not less than thirty on each. In the *menopoma* they occupy the anterior palatine margin of the vomer, forming a line on each side parallel with the maxillary and intermaxillary teeth. In the *axoloth* they are arranged in the quincuncial order, and are numerous. But the most remarkable form and arrangement of the palatine teeth is found in the siren, in which they have the quincuncial arrangement; they are placed on two small bony plates on each side, probably rudiments of the vomer and palatine bones. Each of the larger has six or seven lines of teeth, about twelve on each line; and each smaller bone bears four ranges of five or six teeth; making in all nearly two hundred teeth in the palate. Those of the lower jaw in this animal are placed in similar order. In the proteus the teeth nearly resemble those of the salamander.

The maxillary teeth are always slender, sharp-pointed, and closely set. The frog has about forty on each side of the upper jaw, of which eight belong to the intermaxillary bone. The salamander has about sixty above and below.

In the tadpole state of the frog the mouth is very small, and, instead of teeth, is occupied only by minute horny plates of just sufficient consistence to abrade the soft mixed food which it finds on the surface of animal or vegetable substances in the water. Its stomach and intestinal canal are of very different form from that which they afterwards assume. The intestine is of nearly equal size throughout its whole length. It is very long, being not less than ten times the length of the actual space from the mouth to the anus, and is coiled up in a circular form, occupying the greater part of the abdominal cavity. The canal, as we shall presently see, changes its character materially during the metamorphosis of the animal, becoming gradually shorter until it is not a quarter of the length, in proportion to the size of the animal, which it exhibited in its earlier condition.

In the adult amphibia the whole alimentary canal is of a very simple character. The œsophagus is wide and comparatively short. The stomach single, consisting of a simple sac, elongated in the lengthened forms of the salamander, the proteus, and other aquatic species. The intestine is but slightly convoluted, even in the short tailless family; and there is comparatively little difference in the diameter of its two distinct portions. It terminates, as in the reptilia, in a cloaca, or pouch, which also receives the openings of the urinary and genital organs. The anus in the toads and frogs opens on the hinder part of the back; in the other forms it is situated beneath at the commencement of the tail, as in the reptilia.

The liver, the pancreas, and the spleen are found in the whole of the amphibia; and these organs are observed, in the elongated aquatic forms, to assume a corresponding lengthened shape. The liver is of considerable size, particularly in the salamanders. The gall-bladder exists in all cases, varying, however, in size and form in the different genera.

IV. *Lymphatic and lacteal system.*—This system is highly interesting in the amphibia, on account of its extreme development, and of its presenting several important and remarkable peculiarities in its structure.

The investigations of Professor Muller of Berlin have lately brought to light the existence of pulsating cavities in the course of the lymphatics, constituting a sort of ventricles for the propulsion of their fluids towards the veins into which they are received. In the frog two pairs of these little pulsating sacs are found; at the posterior part one is situated on each side of the extremity of the coccygeal bone, behind the hip-joint, and the anterior ones under the posterior edge of the scapula by the transverse process of the third vertebra. These cavities are of considerable size, and pulsate with some degree of regularity: the pulsations, however, do not coincide with those of the heart, nor are those on the one side always synchronous with those on the other. The posterior ones convey the lymph received from the legs and hinder parts of the body into the ischiatic veins, and the anterior pair, into which the absorbents of the arms and the anterior parts of the viscera, &c. open, convey this fluid into the jugular veins. The internal structure of these sacs is cellular; they communicate freely with each other on each side by anastomosing vessels. On inflating the organ, not only the lymphatic vessels are inflated, but the whole of the veins also. Dr. Marshall Hall had previously observed a somewhat similar pulsating cavity in the eel.

These lymphatic ventricles in the amphibia have still more recently received further examination and illustration by Professor Panizza of Pavia, who published the result of his researches in the year 1833.* Professor Muller's discovery was published in the previous year in the Berlin Annals.

The lymphatic system is developed to an extraordinary degree in the frogs, as well as in several other genera of this class, its vessels being found in numbers and of considerable size immediately under the skin.

The lacteals ramify upon the surface of the intestine in two layers, anastomosing and forming intricate plexuses on the mesentery, and terminating in two trunks, or thoracic ducts, which pass forwards one on each side of the spinal column.

V. *Of the sanguiferous system.*—If the changes, so frequently alluded to, which the animals of this class undergo in passing from the condition of a fish to that of a reptile, have received repeated illustrations in the consideration of the structure of the skeleton, of the organs of motion, and of those of digestion, far more interesting and important are those which occur in the character of the circulation; in which the view which has been taken of the true situation of the amphibia in the chain of animal development receives the most satisfactory proof. Beginning life with all the essential characters of the fishes, even in the functions of circulation and respiration, possessing the single branchial heart of that class, how wonderful and beautiful are the changes which these systems of organs undergo, as the branchiæ become obliterated to give place to pulmonic cavities, and the heart at the same time assumes the compound character and form of a systemic and pulmonic heart, in accordance with the change in the respiratory organs.

The newts, or water-salamanders, afford the most satisfactory opportunity of observing these

* Sopra il sistema linfatico dei rettili. fol. Pav. 1833.

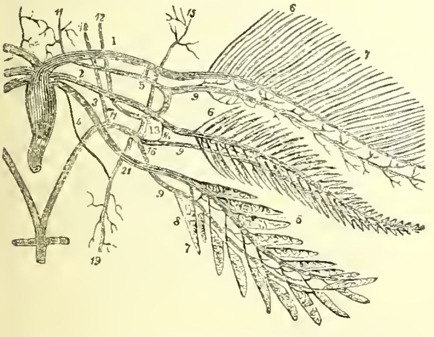
changes, as the branchiæ are large in proportion, and remain external during the whole period of their existence; the animal also acquires considerable size before these organs of aquatic respiration are lost. The heart in the early stage of these animals consists of a systemic auricle, which receives the whole of the blood from the system after circulation, and of a ventricle which propels it through a third cavity, the *bulbus arteriosus*, to the branchial arteries, of which there is one given to each branchial leaf. From the capillary branches of these arteries the aërated blood is received by the branchial veins, which, as in fishes, concur to form an aorta without an intervening ventricle. From the last, or posterior branchial artery, on each side is given off a branch which goes to the rudimentary pulmonic sac, and which ultimately forms the trunk of the pulmonary artery. But the most interesting and important change is that by which the continuous branches of what were originally the branchial arteries combine to form the two trunks of the aorta. This is effected by means of small communicating branches between the branchial arteries and the branchial veins, which, as the branchiæ become absorbed, and their minute branches are obliterated and lost, gradually enlarge until they become continuous trunks; and the artery, which was originally branchial, then becomes the single root of the two descending aortæ, and at its base gives off the pulmonary artery.

The two veins which return the blood from the rudimentary air-sacs gradually enlarge as these cavities become more important, and assume the character of lungs; and at length they receive the name, as they perform the function, of pulmonary veins. These by degrees become, as it were, distended at their point of union with the heart, and ultimately form the second auricle.

This general description will be better understood by a reference to the subjoined figures taken from the tabular views of M. St. Ange, of which an English edition has been published by Mr. Jones.*

The following detailed description of those figures is necessary to the correct understanding of this intricate but interesting arrangement.

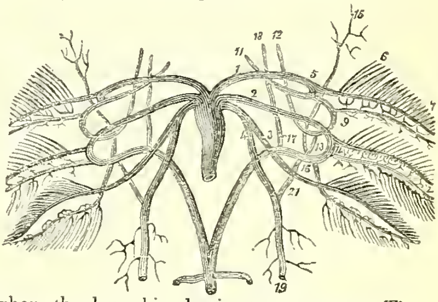
Fig. 18.



The first period, previous to any change having taken place in the branchiæ, is given in *fig*. 18. Four pairs of trunks (1, 2, 3, 4) go off from the heart. The first branch on each side (1) gives off a small anastomotic branch (5); after which it becomes divided into numerous branchial filaments (6); these, by their ultimate subdivision, terminate in a capillary tissue or network (7), from which arise other minute returning vessels, forming, by their junction, a single large vessel (9), which brings back blood into the general circulation after it has been aërated in its course through the branchiæ. The second branch (2) also gives off a small one (14) previously to its subdivision in the second branchial leaflet, which branch enters the returning vessel; thus producing a communication between the two vessels 2 and 9, as in the former case. The returning vessel then terminates in the arch of the aorta, in which the two vessels 13 and 15 also terminate. The third principal vessel (3) is similarly distributed on the third branchial leaflet, and the corresponding returning vessel (16) terminates in the aorta, as in the other case. The arch of the aorta, thus formed, gives off a branch (21), which, after receiving the fourth branch from the heart (4), goes into the lungs (19).

The second period, shewn in *fig*. 19, occurs

Fig. 19.

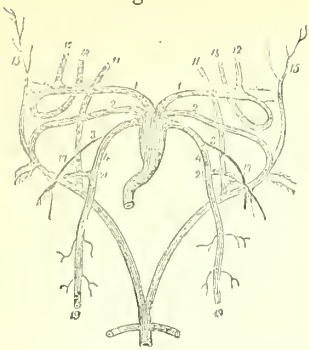


when the branchiæ begin to contract. The anastomotic branch (5), shewn in the former figure, is not much enlarged, and assumes the character of a continuous trunk with 1. The branches (11 and 12) have increased in size, but the original continuation of 1 going to the branchiæ, has decreased in the same proportion. The anastomotic branch (14) has acquired the size of the arch of the aorta, whilst the continuation of 2 is diminished, and the branchial leaflet is contracted in a corresponding degree. The branch 3 has become exceedingly small; and 4, which was before the smallest, is now the largest of all. By these changes in the relative dimensions of the different vessels, especially in the enlargement of the anastomotic branches, the whole system of the circulation is gradually being altered, until, in the third period, (*fig*. 20,) it has assumed the character of that in the reptile, by the total obliteration of the branchiæ and their vessels, and the enlargement of those branches, which, at first only anastomotic, have now become principal.

In the adult condition of the animal, there-

* Tabular view of the circulation in vertebrated animals.

Fig. 20.



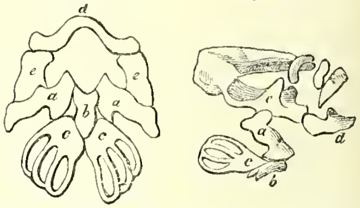
fore, the heart consists of a single ventricle, and of two auricles. The existence of a second auricle was first demonstrated in the higher forms, the frogs and toads, by Dr. Davy,* and, although in the latest works of Cuvier and Meckel the auricle in these forms is described as single, yet the more complicated structure has since been amply confirmed by many other anatomists. Weber† especially has described the biauricular structure in a large American frog; but he failed to demonstrate it in the perennibranchiate amphibia. From a very interesting paper by Mr. Owen, in the first volume of the Zoological Society's Transactions,‡ it appears that the biauricular structure of the heart was ascribed by Hunter to all the amphibia except the perennibranchiate forms; in which, however, the existence of the left auricle has been satisfactorily determined by Mr. Owen, who has also given some very interesting illustrations of the mode in which the coexistence of branchiæ and rudimentary lungs is associated with certain peculiarities of the circulation. The circulation in the adult *amphibia*, then, assumes exactly the character which we find in the *reptilia*, but in the most simple form.

The little pulmonic auricle receives the blood perfectly aërated from the lungs by means of the pulmonary veins. The systemic auricle at the same time receives the impure blood from the system by the venæ cavæ. The blood from the two auricles is sent together into the single ventricle where it becomes mixed, and this mingled arterial and venous blood, thus but half purified, is propelled by the same impulse, partly into the pulmonary arteries to be more perfectly purified, and the remainder through the aorta and the whole circulating system to the different organs of the body. The aëration of the blood, therefore, is but imperfect; a condition which is met with equally in the whole of the reptilia.

VI. *Respiration.*—The preceding observations on the circulation have in some measure necessarily anticipated the account which we have to offer of the correlative function of respiration, and the character of those changes to which its organs are subjected in the transit of the amphibia from the pisciform to the reptile state. Breathing water, in the first instance, exclusively, these animals are furnished in the tadpole condition with branchiæ or gills, of a leaf-like form, considerably subdivided, though far less so than in the fishes. These branchiæ are, in the first instance, in all cases external; but in the higher forms of the class they remain so situated only for a brief space, becoming, as in the frogs and toads, internal at a very early period of their existence. They are supported by cartilaginous or osseous arches, connected with the os hyoides, and the changes which they undergo are accompanied by alterations in the form of that bone, to which allusion has already been made, and an account of which will now be given.

At that period of the tadpole's existence, at which its branchiæ are in full action, and the lungs still restricted to the state of a blackish, rudimentary tissue, we find the tympanic bones, (*figs.* 21, 22, *e*,) developed to a great

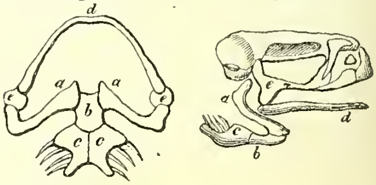
Fig. 21. *Fig.* 22.



extent, and forming the basis to which the branchial apparatus is suspended, by means of a rather thick angular portion, (*figs.* 21, 22, *a*.) This has been shewn by Cuvier to represent what in the fishes is composed of three bones, and is the medium by which in them the whole branchial apparatus is suspended to the temporal, and which bears also the branchiostegous rays. Between these two lateral branches is a single piece, (*figs.* 21, 22, *b*,) which, according to the same authority, corresponds to the chain of bones placed in most fishes between the two first branchial arches. To the posterior point of this bone are attached two rhomboidal portions, (*c*, *c*,) to the external margins of which are suspended the arches on which the branchiæ are supported, and which represent the chain of bones in fishes, bearing the two last branchial arches.

As the age of the tadpole increases, and its metamorphosis is proceeding unseen, (*figs.* 23, 24,) we find the branches which support

Fig. 23. *Fig.* 24.



the branchial apparatus (*a*) gradually lengthening, and becoming more and more slender, and at length exhibiting the two long cartilaginous pieces, by which the os hyoides is

* Zool. Journal, vol. ii.
† Beitrage von dem Herzen der Batrachier, 8vo. 1832.
‡ Part iii. p. 213.

attached to the cranium; (*fig.* 25, *a*,) the single piece (*b*,) and the two rhomboidal pieces (*c*, *c*,) in the meantime become united and extended, (*figs.* 25, 26,) and gradually lose by absorption

Fig. 25.

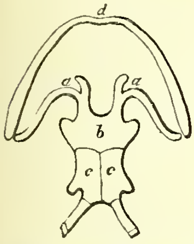
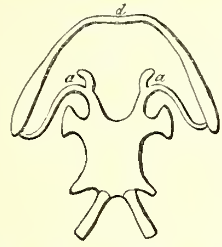


Fig. 26.

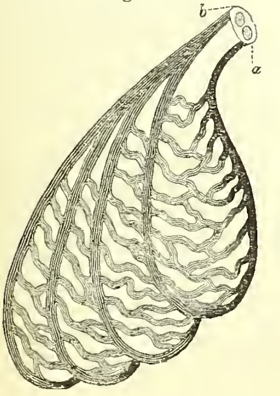


the branchial arches, and ultimately form a broad disc, the body of the os hyoides, the anterior margin of which on each side is dilated into a scutiform process, and the posterior margin bears two bony appendages, which are, in fact, the posterior cornua of that bone.

Such are the changes which this bone undergoes during the gradual passage of the amphibious animal from the tadpole state, in which it represents the class of fishes, to its perfect or reptile condition; and it affords a most interesting instance of the manner in which the true nature of an organ, existing under ambiguous circumstances in one class of animals, is often clearly illustrated by its characters, or, as in the present instance, by its transformations, in another.

The minute filiform branchiæ, which are appended to the tadpole of the frog immediately behind the head, have essentially the same structure as is observed in the gills of the perennibranchiate family, as the *siren* and the *proteus*, though in a different form. In the *proteus* each branchia consists of three principal divisions or branches, from each of which proceed seven or eight leaves, again subdivided into numerous regular leaflets forming the ultimate divisions of the branchiæ, on which the extreme capillary branches of the vessels ramify, and in which the blood undergoes its necessary change. A minute ramification of the branchial artery, conveying the impure blood from the heart, enters each leaflet at its base, (*fig.* 27, *a*.) and passes, along

Fig. 27.



its shorter or inner margin, giving off capillary branches in its course, which, after meandering over the surface of the leaflet, and communicating with each other in various directions, pass over to the opposite margin of the leaflet, and reunite in a corresponding ramification of the branchial vein (*b*), which passes out at the base to combine with the corresponding branches from the other leaflets, and convey the aërated blood back to the heart. This is the general structure, modified however in the different genera, by which this important function is effected in all the amphibia, as long as they are confined to their aquatic life; and whilst the higher groups lose these organs as they advance, and acquire the necessary organs for atmospheric respiration, those of the lower forms retain them throughout life, coexistent with rudimentary lungs; and thus probably exhibit the remarkable phenomenon of a twofold mode of respiration at one and the same time in the same individual.

Such, then, is the general structure of the organs of aquatic respiration, whether in the early and transitory form in which it is seen in the frog and the salamander, or in the permanent character which belongs to it in the perennibranchiate group of the siren, the axolotl, the menobranchus, and the proteus. But as the former of these groups acquires gradually a perfect and unmixed atmospheric respiration, and as the pulmonary cavity serving this office is only slowly developed, so we find in the perennibranchiate forms that the lungs also exist, though in little more than a rudimentary state. The early condition of the lungs in the caducibranchiate genera, in which they ultimately exhibit a somewhat advanced structure, is that of a mere rudimentary sac, without internal cells or any appearance of even the commencement of that more perfect structure which they afterwards acquire. Gradually, however, the inner surface is furnished with small processes, forming little sacs or cells, on which the capillary branches of the pulmonary vessels ramify, and through the infinitely attenuated surfaces of which the impure blood undergoes its essential process of depuration.

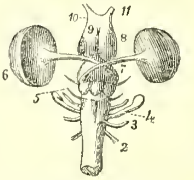
In the lower forms of the class, as in the *proteus anguinus* for instance, the air-bags, for they scarcely deserve the name of lungs in this state, never arrive at this advanced stage of development, but remain permanently in the condition of simple membranous sacs. Every part of the apparatus belonging to that organ is equally rudimentary. The glottis consists of nothing more than a small slit in the lower part of the fauces, placed between the branchial apertures of each side. The margin of this little opening, which has no cartilaginous ring to support it, is furnished with a small soft pair of muscles, by which it is opened. The tube leading from this opening speedily bifurcates, and one passes to each air-bag. In this rudiment of a trachea and of bronchi, there is no appearance of cartilaginous rings; it is a mere membranous canal, each branch of which opens without any other apparatus into its air-cell. From the perfect condition of the branchiæ, and the very simple structure of these pulmonary sacs, it will readily be seen that the function of respiration could be only very ineffectively aided by the latter organs, even were there no other difficulty arising from the imperfect structure of the apparatus which in the air-breathing amphibia serves the office of conveying the air into the lungs. A short description of the means by which the act of inspiration is effected in the frog will enable us to judge how far it may be *possible* that the rudimentary lungs in the *proteus* and *siren* are to be considered as performing any such function.

In the adult frog, toad, salamander, and all others of the higher orders of amphibia, the reception of air into the lungs is effected not by the primary expansion of the pulmonic cavity and the consequent rush of air into it, but by the act of forcing air into the lungs, or in fact by a simple act of swallowing. This is effected in the following manner. The os hyoides and tongue are brought downwards to a considerable extent, and the cavity of the mouth being thus much enlarged, the air enters by the nostrils. The pharynx is then shut at the posterior part, so as to prevent the passage of air into the œsophagus, and the cavity being suddenly contracted by means of the muscles acting on the *os hyoides*, the air is necessarily forced through the glottis and trachea into the lungs, as the posterior nares are closed either by their margins acting as a valve, or by the pressure of the tongue against them. This view of the mode of inspiration explains the cause of the well-known fact, that if the mouth of frogs be held open they perish from actual suffocation; for the motions of the os hyoides being thus impeded, and an external passage being also afforded for the air, respiration by the injection of air into the lungs is obviously impossible. Any other mode of inspiration, connected with the primary expansion of the thoraco-abdominal cavity is obviously impossible in the frog and its congeners, from the total absence of ribs. It may not be out of place to explain here the mode in which the peculiar noise uttered by the male frog, called croaking, is produced.* According to the observations of P. Camper, the inspired air is forced against the inferior surface of the tongue, the protuberance of which divides it as it were into two currents, which pass into the membranous sacs adhering to the lower jaw and existing exclusively in the males. From these sacs it is directed over the tongue, and by its vibration the peculiar sound in question is produced.

It is an interesting question whether in the perennibranchiate amphibia, the organs which have just been described as rudimentary lungs, do ever serve the purposes of respiration in even the smallest degree; and it is one of no small difficulty. The superficial structure of the nares in the siren and the proteus, in which they almost exactly resemble those of fishes, and which would preclude the mode of inspiration practised by the frogs, together with the slight and attenuated character of the membranous tube and sacs, would almost lead to the conclusion, assumed by Rusconi, that in the proteus at least these organs do not exercise any function appertaining to respiration. If these animals be confined for a considerable time in the same water, the branchiæ become purple instead of having the florid red colour which characterizes them in a healthy state, and they die asphyxiated. On the other hand, the very excitement of the two sacs, accompanied by tubes of such length, and opening to the pharynx by a sort of simple glottis, governed by a distinct muscular apparatus, would seem to warrant the opinion that a nearer affinity to true lungs is to be traced in these organs than in the air-bag of fishes, though recent observations have shewn the latter organ to be analogous to the lowest rudimentary state of lungs in the higher animals. The chain of affinities, therefore, is here perfect, as far as regards the pulmonary cavities.

VII. *The nervous system.*—The centre of the nervous system offers a not less striking instance of the progressive development of the amphibia in their passage from the pisciform to the reptile state than those which we have already shewn in the organs of the other functions of the body. The condition of the brain in the early state of the frog tadpole, the genus in which the changes are most strongly marked, is almost exactly that which it possesses in the fishes. The linear arrangement of the different lobes, the broad and lobed form of the medulla oblongata, the small cerebellum, the large size of the optic thalami, with the distinct ventricles which they contain, and the very diminutive extent of the hemispheres, all evince a low degree of development, and one not yet emerged from that which we find in the brain of fishes. The same imperfect character is also observed in the spinal marrow, which even in the frog is continued into numerous coccygeal vertebræ, and as the extremities are not yet in existence, is devoid of those enlargements which afterwards take place where the nerves of the anterior and posterior members are given off. The brain becomes developed, however, in a very short period; the changes which take place being very rapid, though at last not very considerable; the hemispheres become enlarged, expanding laterally and in some measure upwards, constituting the first step towards that superiority in position, as well as in size, over the other lobes, which is so conspicuous a character of these important portions of the brain in the higher animals. *Fig.* 28. represents the brain

Fig. 28.



1, pneumogastric nerve; 2, ninth pair; 3, sixth pair; 4, acoustic; 5, facial; 6, the eye; 7, optic nerve and its tubercle; 8 and 9, base of the hemispheres; 10, anterior portion of ditto; 11, pedicle of olfactory lobe.

in the common frog after Serres. As the limbs begin to make their appearance, the enlarge-

* Comment. Soc. Reg. Scient. Götting. v. ix.

ments of the spinal cord are observed to take place, and the contraction of the coccygeal vertebræ into a single linear bone, is accompanied by a corresponding diminution in the length of that part of the spinal marrow, which at length only extends, in the form of a small filament, into the anterior third of that bone.

The inferior condition of the brain which has been described as existing in the tadpole of the higher species, is permanent in the proteus and other perennibranchiate genera; so that the brain of the animal just named bears a very obvious resemblance to that of the larva of the aquatic salamander or *triton.*

VIII. *The organ of vision.*—The eye differs considerably in its form and magnitude in different genera of the amphibia, and without any very apparent relation to either their habits or their circumstances. In the frogs and some others they are remarkably large and prominent; in the salamanders they are comparatively small, though from their at least equally aquatic habits, this difference might perhaps have scarcely been anticipated, and in the cœcilia, as the name imports, the eyes are scarcely if at all visible. In the latter animal the same object has doubtless been intended by this absence of vision, as in the mole and many other animals, whose common subterranean mode of life would render the possession of acute sight not only generally useless, but an extreme inconvenience on their occasional appearance above the surface.

In some points of their structure the eyes of the amphibia are not remotely related to those of the fishes; as, for instance, in the flattened anterior surface of most of them, arising from the small supply of the aqueous humour, and in the depth of the crystalline. In some of the lower forms, there can scarcely be said to be a true orbit, the eyes being fixed as it were in the integuments, and surrounded by a mass of minute veins, intermixed with extremely small branches of nerves. Rusconi states that in the *proteus* he was not able to discover muscles, nor even the optic nerve; though on carefully and gently raising the hemispheres of the brain a minute nervous filament was seen going towards the foramen which serves for the passage of the ophthalmic artery; but whether this was the optic nerve or not, appears a matter of entire doubt. In fact, the structure of the eye in this animal, on the whole, is very imperfect.

In the frog, on the contrary, the eye is fully developed, and all the essential parts of its structure sufficiently conspicuous. The globe of the eye is large and projecting; the sclerotic is considerably solid and tough, and semitransparent; the cornea is large, and though somewhat flattened, is much less so than in fishes, or in the lower forms of the class. The inner surface of the choroid is extremely black, and the external of a silvery whiteness. The ciliary processes have not with certainty been discovered in these animals, unless, as Altena suggests, a little tubercular mass, occupying nearly their situation, and closely connected with the edge of the choroid and with the capsule of the crystalline, may be a modification of this structure. The iris is covered on its posterior surface with pigmentum nigrum; the anterior having a shining metallic lustre, precisely similar to that which we see in fishes. The contractility of the pupil asserted by Carus is denied by Altena and others. The retina is thick, and covers the whole internal surface to the capsule of the crystalline. The vitreous humour is, in proportion, abundant, and the lens is large and of a spheroidal shape, consisting of numerous concentric laminæ, enclosing a nucleus of extreme density, exhibiting a close relation to the state of this part in fishes. There are in the frog three palpebræ; or perhaps, with greater strictness of analogy, it might be said that there are two palpebræ, and a sort of expansion of the inferior, serving as a *membrana nictitans.* The superior palpebra is small, and is not possessed of any degree of mobility; the inferior is broad, expanded, and semitransparent. It has an internal membranous expansion, which has just been alluded to, and which is capable of covering the whole *eyeball.*

IX. *The organ of hearing.*—The function of hearing exists in very different degrees in the different groups of amphibia. The aquatic habits to which the lower forms are confined by their branchial respiration, would render an acute perception of sonorous impulses as unnecessary as it would be incompatible with the dense medium in which they live; and we find in this sense, as in every other function of the body, the most perfect concord existing between the habits of the animal and its structural arrangements. The pisciform aquatic genera of this class, therefore, are found to possess as near an affinity to the fishes in the structure of the organ in question as in most others; and in this they are also imitated by the tadpole state of the higher reptiliform groups, the adult condition of which exhibits a much more advanced development of the acoustic organ. In the proteus and the allied genera, there is neither a tympanic cavity, nor membrana tympani; it consists of a large cavity hollowed as it were out of the temporal bone, at the bottom of which cavity is the sacculus with its cretaceous body; the fenestra ovalis is closed by a bony lamina, the representative of the stapes. Behind the sacculus are the membranous semicircular canals. The whole organ is covered externally by the integuments, without any possible communication with the atmosphere.

In the frog, on the other hand, the whole structure is more complicated. The sacculus, which is membranaceous, is filled with the cretaceous matter, which is here semifluid, having the appearance of cream. The semicircular canals are contained within the substance of the temporal bone. The ossicula auditus are three, united, and contained within the tympanum, which they traverse, and are attached to the membrana tympani, a broad round membrane, perfectly superficial, and very distinct from the surrounding integument. The cavity of the tympanum is not capacious. It communicates with the external air by means of an Eustachian tube passing from it to the fauces. In all the essential parts of this structure, there is but little variation from that which exists in the true reptilia.

X. *The organ of smell.*—The nares in the perennibranchiate amphibia are, like those of fishes, confined to little more than a slight cavity on the anterior part of the head, and having no continued canal by which they can communicate with the cavity of the mouth. In the proteus the similarity of this organ to that of fishes is so complete, that even the plicated radiations of the lining pituitary membrane are almost exactly imitated. It is of considerable size, and is contained in a lengthened canal or cavity, the parietes of which are in no part osseous. The nostrils terminate immediately under the upper lip. The olfactory nerves are rather large, and no sooner emerge from the cavity of the cranium than they divide into numerous branches of various lengths, which enter every part of the soft pituitary membrane.

In the more highly developed genera the organ of smell has the more advanced structure which is observed in the reptilia. The nostrils are partly cartilaginous, partly osseous, and extend into the cavity of the mouth, though the posterior openings are placed much more forward than in the higher classes of vertebrata. The olfactory nerves enter the nostrils through two openings in the ethmoid bone. The absence of the convoluted and extensive surfaces of the turbinated bones, the entire simplicity of the canal of the nostrils, and the small extent of its surface, must restrict these animals to a very circumscribed enjoyment of this function; and it is probable that the sensibility to odours is much more acute in the aquatic forms, in which the organs of sight and of hearing are so imperfectly developed, than in the frogs, in which the organs of these senses are much more elaborately formed.

XI. *Of the organ of taste.*—The sense of taste, in all the amphibia, as well as in fishes, is probably very obtuse. The tongue in the *urodela* is small, and attached closely at every part. In the *anoura*, on the contrary, it is developed to an extraordinary degree; it is very long, bifid, and the anterior half is not only free, but, in its quiescent state, doubled back upon the posterior fixed part, and capable of being thrown forwards and again retracted with the rapidity of lightning, serving as a most efficient means of arresting the quickest movements of insects, which it conveys into the back part of the mouth to be swallowed.

The application of the tongue as an assistant in respiration, by closing the posterior nares, in all higher groups of the class, has been before alluded to.

XII. *The dermal or tegumentary system.*—The absence of all hard scaly adventitious covering to the skin of the amphibia is one of the most common, or perhaps it may be said, the only universal peculiarity by which they are, as a class, distinguished from *all* reptilia. The amphibious nature of their progressive development, or the existence at the earliest period of even rudimentary branchiæ, can scarcely be said to be without exceptions, as several genera have already been mentioned as not having yet been observed in this condition. But the naked skin is a character belonging equally to all, from the serpentiform cœcilia to the typically amphibious frog, and the pisciform axoloth and proteus.

The skin of the aquatic genera is soft, smooth, and furnished with a secreting surface, by means of which it is kept constantly moist, and in a state suitable for that cutaneous respiration which strikingly characterises these animals. Many of those which are generally inhabitants of the land, as the terrestrial salamanders, the toads, and others, are provided with numerous cutaneous glands, which secrete a tenacious milky fluid, which is somewhat acrid, and may perhaps be deleterious if swallowed in any quantity; though the old opinion of the poisonous nature of these animals is altogether without foundation. The fluid which is poured out from these cutaneous follicles in the common salamander is copious, of a milky colour, and consists of mucus, with the addition of some acrid matter, the nature of which is not yet known. From the quantity which is suddenly secreted when the animal is injured or any part of the surface irritated, it is not improbable that even the effect of fire may for a few moments be arrested by it; and thus may have originated the fable of the salamander having the power of remaining unconsumed and unhurt when thrown upon burning coals. The acrid nature of the cutaneous secretion of the toad was confirmed by the observations of Dr. Davy a few years since.

The cuticle of these animals is frequently shed; that of the aquatic species comes off in shreds, and is washed away from the skin. In the toads a very curious process takes place for its removal. When the cuticle has become dry and unyielding, and a new and softer surface is required, the deciduous layer splits down the median line of the back and of the abdomen at the same time. The whole cuticle is thus divided into two parts. By numerous convulsive twitchings and contortions of the body and legs, this separation becomes more and more considerable, and the cuticle is gradually brought off the back and belly in folds towards the sides. It is then loosened from the hinder legs by similar movements of those limbs, and finally removed from them by the animal bringing first one and then the other forwards under the arm, and by then withdrawing the hinder leg its cuticle is left under the fore leg. The two portions are now pushed forwards to the mouth, by the help of which the anterior extremities are also divested of it. The whole mass is now pushed by the hands into the mouth, and swallowed at a single gulp. The new cuticle is bright, soft, and covered with a colourless mucus; the old skin was harsh, dry, dirty, and opaque. This curious process I have repeatedly watched. I have observed shreds of cuticle hanging about the terrestrial salamander, which would lead to the opinion that this animal does not disengage itself from its deciduous skin in the same manner as the toad; but as the individuals under notice were not in health, the observation is inconclusive.

But the most interesting circumstance connected with the functions of the integuments of these animals, or indeed with any part of their economy, is their cutaneous respiration, or the power which the dermal surface possesses of effecting those changes in the blood, which are essential to life, and which are usually performed by particular organs set apart for that express object, and modified according to the aquatic or atmospheric medium in which the depurating agent is applied to them.

Although the experiments of Spallanzani had long ago demonstrated that carbonic acid was produced by the contact of the atmosphere with the skin of frogs, the subject had never been examined with the care and attention which its importance demands, until the investigations of Dr. Edwards of Paris, given in his work "On the Influence of Physical Agents on Life," set the question at rest, and established the proposition by a series of interesting experiments, so admirably arranged, so satisfactorily conducted, and so logically reasoned upon, as to leave no vacuity in the regular line of induction, nor doubt of the strict correctness of his conclusions.

The existence of a cutaneous respiration in frogs was proved by the simple experiment of tying a piece of bladder over the head so tightly as to produce complete strangulation, and then placing them under water. On examining the air contained in the vessel after an hour or two, a sensible quantity of carbonic acid was detected.

On placing frogs in vessels filled respectively with river water and with water which had been deprived of its air by boiling, and inverted over the apertures perforated in the shelf of a pneumatic trough, containing ninety-eight and a half pints, those in the latter lived on the average little more than half as long as those in the aerated water. On trying the effect of stagnant water renewed at intervals, they were found to live two months and a half, and then died from accidental neglect of renewing the water. Similar results followed experiments made under running water. The effects of temperature in these experiments were very striking, and prove that the duration of life under water is in an inverse proportion to the elevation of the temperature from 32° to about 107, at which point the animals die almost instantly. But these effects of temperature were found to be modified by an increase of respiration, whether by their rising to the surface and breathing the atmosphere, or by the quantity of aerated water being increased.

Such is a rapid glance at some of the results observed by this distinguished physiologist, on the cutaneous respiration of aërated water; those which are connected with atmospheric respiration by the same surface are no less interesting. In order to render the experiments as rigorously satisfactory as possible, pulmonary respiration was prevented by actual strangulation, rather than by keeping the mouth open, a method which appears liable to some degree of uncertainty. A ligature was passed round the neck of six frogs, using the most rigid compression, so as completely to exclude any possible passage of air. One of them lived twenty days; those placed in five ounces and a half of water had died in from one to three days. As the severity of the operation of strangulation might probably have hastened death, another mode was tried, namely, the total excision of the lungs,—an operation which appeared to produce but little suffering; the animals were then placed on moist sand. Of three frogs thus treated, two died on the thirty-third day, and the remaining one on the fortieth.

Other experiments were instituted to resolve the converse of the former proposition, whether life can be prolonged by pulmonary respiration alone, unaided by that of the skin? The result of the experiments made upon tree frogs and upon the *bufo obstetricans*, was that pulmonary respiration is not sufficient to support life, without being accompanied by the influence of the skin.

The results of these experiments are not only highly interesting as regards the habits of the particular tribe of animals which were the subject of them, but still more so with reference to some important questions in general physiology; but as their bearing on these points can only be shown by viewing them in relation with all the other subjects treated of in the admirable work from which they are taken, it would be out of place to consider them here. It is impossible, however, not to be struck with the evidence they afford, that the respiratory organ, that surface through the medium of which the blood undergoes its necessary change by the action of oxygen, whether pulmonary, branchial, or cutaneous, and whether the medium of its access be water or the atmosphere, is in all cases similar, being a modification of the cutaneous surface. And as we see in the instance before us, the same surface capable of performing either atmospheric or aquatic respiration, the inference is obvious, that pulmonary and branchial organs may, and probably do, possess an identity of structure. When it is considered too that moisture is absolutely essential to atmospheric respiration, whether pulmonary or cutaneous, the identity of the two processes becomes still more unequivocal.

This view of the subject receives considerable confirmation from the fact that branchiæ are in many animals capable of exercising the office of atmospheric respiration through the medium of a very small quantity of water; as the land crabs of torrid regions are enabled to traverse immense districts under a burning sun, by means of those little reservoirs of water, described by Dr. Milne Edwards, formed by duplicatures of the lining membrane of the branchial cavity. The eel too, as is well known, will live for a long time out of water, from its branchial cavity being capable of retaining a sufficient quantity of water to bathe the branchiæ for a considerable time, thus preserving those organs in a respirable state.

XIII. *Of transpiration and of secretion.*—The particular condition of the skin already described, naked and consisting of a moist mucous surface, would render it probable that cutaneous transpiration should be exceedingly extensive and rapid in these animals; this is in fact the case to such an extent, that when exposed to too great a degree of heat, the evaporation of transpired fluid is sufficient to produce a very rapid decrease in the weight of the animal; which, if exposed for a sufficiently long period to its influence, becomes almost dried up and dies.

One object, and that not an unimportant one, of the sensible transpiration of fluid in these animals, the frogs especially, is undoubtedly to preserve the skin in a condition fit for the performance of that cutaneous respiration which has been described. But its still more obvious purpose is to afford a quantity of fluid for evaporation from the surface, in order to reduce and equalize the temperature of the body when exposed to a degree of heat, sufficient to incommode or injure it. This will appear very reasonable when we reflect that these animals will die in a few minutes, if placed in water of 107 degrees of Fahr., though respiring freely with the head above the water, whilst, on the contrary, they will support for hours the action of damp air of the same temperature.

The water which is thus transpired is not the result of the absorption of fluids taken in by the mouth, for these animals do not appear to drink. It is received by absorption on the surface of the skin, to which part it is afterwards restored when necessary. But in order to be ready whenever circumstances call for its use, the fluid thus absorbed is conveyed into a membranous cavity, formed generally of two lobes, opening into the cloaca, where it is retained, to be again absorbed, and again conveyed to the surface for the purposes just mentioned. When a frog is suddenly alarmed, or seized, it ejects from its cloaca a quantity of pure, limpid water, for the purpose of lightening itself, that it may leap with greater facility. This fluid is expelled from the sac in question, and is often mistaken for urine, and the sac for a urinary bladder. Hence, if a frog be kept in a moist situation, without having access to water in any form but in vapour, the skin is always kept moist, and the water-bag always filled.

Such is the function attributed in the first place by Townson to the sac in question, and after him by Dumeril, Altena, and others; but Cuvier, Dr. Grant, and many other anatomists consider that it is the true urinary bladder. That Townson's opinion is correct appears, says Altena, "from the circumstance that the ureters do not terminate in the bladder, but in the rectum itself." Dr. Grant states, that on the contrary, "the bladder receives the ureters."

The kidneys are of a lengthened form, in the aquatic genera, but are shorter in the frogs and other *anoura*.

XIV. *On the restoration of lost parts.*—The fact that parts lost by accident, or removed for the purpose of experiment, become reproduced in many of the lower animals, has been known for ages. The actual multiplication of the species in many, perhaps all the polygastric animalcula, by spontaneous separation,—that of the hydra by artificial division,—the restoration of lost arms in the different species of asterias, of the anterior or posterior extremity of the body in the earthworm, of the claws of the lobster, and other crustacea, and of portions of the head in the pulmoniferous mollusca, are, all of them, phenomena which have attracted the attention, and occupied the experiments of physiologists, at various periods. The experiments of Plateretti, Spallanzani, Murray, Bonnet, and others, have shewn that it is not in the invertebrate forms alone that we are to look for this phenomenon, but that the amphibia, and even some reptilia, will reproduce either the limbs or the tail, when removed. This restoration of the tail in the saurian reptiles is indeed a common occurrence, and it often happens that the new tail is double through the whole of the restored length.

Of all the observers of this curious phenomenon in the amphibia, Bonnet* stands preeminent for the laborious and patient zeal with which all his experiments were conducted, no less than for the conscientious strictness with which they are recorded. In many experiments he cut off the anterior or posterior limbs of the common water salamander or triton, which he found to be invariably restored, and even the toes were reproduced, and acquired some degree of motion. The tails were also amputated at various distances from the base, and were always renewed. The same limb was in some cases removed and restored four times consecutively. In all cases it was observed that warmth encouraged and that cold retarded the regeneration of the part. The restored portions were not generally well-formed, but in some instances varied by excess, in others by defect. One of the most extraordinary results was that which followed the extirpation of an eye from one of these animals. In the course of a year this organ was completely restored, and its organization was found to be perfect.

Dumeril records a remarkable experiment of this nature, in his latest work on the reptilia. The subject was the *triton marmoratus*. Three-fourths of the head were cut off, and the animal was deposited at the bottom of a large vessel having half an inch depth of water, which was constantly renewed. It continued to live, and to move slowly. The

* Œuvres, in 4to. Neufchatel, 1769.

nostrils, the tongue, the eyes, and the ears were gone; the animal could therefore enjoy no relation to external objects but by the sense of touch. It nevertheless evinced consciousness, creeping cautiously and slowly about, occasionally raising the neck to the surface as if attempting to breathe. The process of cicatrization at length completely closed the apertures of respiration and of deglutition. It lived three months after the operation, and then died from accidental neglect. After all, this experiment proves only the respiratory function of the skin, a fact already sufficiently established by the observations of Dr. Edwards before detailed, and its cruelty does not appear to be compensated for by its results.

XV. *Of reproduction.*— The impregnation of the ova in the amphibia, is effected without actual coitus; that is to say, it either takes place out of the body, as in the *anoura*, or the impregnating fluid is received by the mere contact of the external opening of the cloaca in the two sexes, as in the tailed forms. The only exception to this statement is in the land salamander, the male of which has a small intromittent organ. The act itself of impregnation therefore differs materially in these two divisions of the class. The generative organs of both sexes are double, and are placed symmetrically in the abdomen. The testes in the higher forms of the class, the frogs and toads, are small globular oval bodies, having externally a bright white appearance, from the tunica albuginea, and internally a somewhat loose texture, and a yellowish colour. They are placed behind the liver, attached to the vertebral column; the vasa deferentia are numerous, disposed in pairs; they form a small epididymis, and passing on the outer side of the kidneys back towards the cloaca, dilate into vesiculæ seminales, just before they terminate in that cavity. These organs, as in many other animals, become much enlarged at the breeding season.

The ovaria are situated in the anterior and upper part of the abdomen, and are internally divided into numerous sacs, by duplicatures of the peritoneum, by which also they are bound to each side of the spine. These sacs are torn at the period of depositing the eggs, whether by the pressure of the arms of the male, as asserted by Prevost and Dumas, or otherwise, appears uncertain. The oviducts are small at their commencement, and become large towards their termination in a sort of dilated sac, which Altena terms the uterus; they are of a pulpy substance, having an internal secreting surface; and the eggs during their passage through them become enveloped in a gelatinous mass. They dilate into a sort of uterine cavity just mentioned, which opens into the cloaca.

The mode by which the eggs of the frog pass from the ovaries into the oviducts appears yet to be doubtful. The observations of Prevost and Dumas on this subject are generally received as correct, but their statements are denied in some particulars by Altena, and doubted in others. They state that the ova, detaching themselves from the ovaries, are seized by the opening of the tube, but they do not state the mode by which this act is effected. It is a question which was long since examined with great care by Swammerdam, and which brought him into a controversy; and he confesses at last his ignorance of the mode in which it actually takes place.

The ovaries enlarge greatly at the breeding season, and the ova at the time of their deposition fill the body almost to bursting. At the time of impregnation the male placing himself on the back of the female, embraces the body with astonishing force with the anterior legs, which are pressed under the axillæ, and the tubercular thumbs, which are at this period considerably enlarged to enable him to retain his hold, are so essential to this object, that if they be cut off, he can no longer clasp the female with the requisite force. The instinct which instigates the male frog to this act at the season of breeding is astonishingly powerful, and sometimes no less remarkably blind. Thus, it is recorded by Walter, and has been often observed by others since his time, though the object of this curious fact has been unaccountably overlooked, that frogs are occasionally found in the spring adhering with great force to different parts of the skin of pike; and a near relative of the writer of this article has seen an instance of the same kind, where several frogs were so closely fixed to a large pike as to require some force to remove them. This instinct of adhesion is, in fact, sometimes fatal to its legitimate object. I have before now taken from the water a large conglomeration of male frogs, amounting to perhaps twelve or more, with one solitary female in the middle of the mass, dead and putrid, and even some of the males, towards the interior, pressed into an almost lifeless and shapeless lump.

While the male is thus closely embracing the female, an operation which sometimes lasts for more than a month, the eggs, to the number of several hundreds, are gradually ejected from the cloaca, either in masses as in the frog, or in double chaplets as in the toad, and impregnated by the sprinkling of the semen, as they pass out under the male. In some species, as the *bufo obstetricans*, the female is assisted in the act of expulsion by the hinder legs of the male. When the eggs are thus deposited in the water, the jelly-like substance in which each is enveloped absorbs a large quantity of it, and the whole mass speedily enlarges to many times the size of the animal from which it was expelled.

The male of the bufo obstetricans just mentioned, when, by his assistance, the eggs are excluded, attaches them to his thighs by glutinous threads, and carries them about with him until the young are ready to leave them, when he seeks a pool of water in which he deposits them, and the young shortly afterwards come forth.

The impregnation of the tailed aquatic

genera, as the tritons, is effected by a totally different mode. During the spring, the males acquire a considerable dorsal membrane, which runs the whole length of the back and tail, and is sometimes curiously indented or fringed at its edge. This membrane is gradually lost after the breeding season, and its use appears to be to assist in the act of impregnation. The male, instead of adhering to the female like the frog, swims by her side pursuing her in all her rapid and changing courses through the water, till at length both remaining for a moment quite still, he suddenly turns up, by the assistance doubtless of the dorsal membrane, and places for an instant the edges of the cloacal aperture in contact with hers. It is at this instant that the semen is ejected and received. The eggs are afterwards deposited slowly, and comparatively few in number, upon some part of an aquatic plant, on which the female supports herself by holding by her hinder legs.

When the embryo has gradually acquired its larva development, and is ready for its aquatic life, it bursts the thin membrane which encloses it, and emerges in the fish-like form which has been so often alluded to in this paper.

XVI. *Metamorphosis.*—The changes which take place in the different organs during the progress of this extraordinary phenomenon, have been already detailed. It remains to trace the general form of the animal from the egg through its larva condition till it receives its permanent form, and to point out some remarkable peculiarities observed in different genera.

In the frog, the toad, and probably all the *anoura*, the respiratory organs undergo a double change, the branchiæ being first external for a very brief period, and afterwards internal during the remainder of its larva existence. In all the other forms in which branchiæ have been detected, they remain external till they are lost.

The tadpole, whether of the *anoura* or of the *urodela*, possesses, at first, as we have seen, the same means of progression as belong to the class of fishes. That of the triton retains its branchiæ, co-existent with four perfect legs, until it is about a third of its ultimate length. In the frog the legs which first make their appearance are the hinder ones; and from the great development of the tail, and the continuous form of the head or abdomen, they appear as if they came through immediately behind the head.

As the terrestrial salamander, though preferring moist places, does not frequent the water, the young have not the opportunity of being developed in that medium; but as the essential character of their organisation requires that the first portion of their existence should be passed in the condition of a tadpole or larva, we find that the whole of its metamorphosis takes place whilst in the oviduct, where it is found with small branchiæ on each side of the neck, which are lost as the animal enters upon its terrestrial existence. Like the viper, therefore, this animal is ovo-viviparous.

The arrest of the metamorphosis in the lower or perennibranchiate forms is confined to the organs of locomotion in part, to those of circulation, and of respiration. The organs of reproduction receive their full development, though even in these there is a considerable resemblance to those of the fishes.

One of the most remarkable peculiarities in the whole of this class, with regard to the subject now under consideration, is the reproduction and metamorphosis of the pipa or Surinam toad. It has long been known that the eggs are developed in cells on the back of the mother; but the facts connected with this curious circumstance have only of late years been ascertained It is now established that the cells on the skin of the female are not persistent, but grow as the eggs enlarge, and are removed after the young leave them. The male impregnates the eggs as the toad, but immediately places them on the skin of the mother's back; here they are attached by a tenacious mucus, and the skin gradually thickens in the interstices, forming at length a cell around each. In these cells the young ones not only leave the eggs, but actually undergo their metamorphosis; and when they leave the back of the parent, they have lost all the characters of the tadpole, and have become perfect animals.

It is impossible to contemplate the structure and habits of this remarkable class of animals without being struck by the many interesting points which they offer for the investigation of the physiologist. Whether we consider the evident and perfect transition which many of them present, from the form and structure of an inferior to that of a superior type or organization, the facilities which they afford us of tracing, as it were under the eye, those mysterious changes and grades of development which in most cases are accessible only at particular epochs, or are wholly concealed during their progress in the hidden recesses of the reproductive organs, or whether we view the modifications which they present of the respiratory and other important functions of life, it is not, perhaps, saying too much to aver that there is scarcely any class of animals which invites the study and contemplation of the lover of physiological science by phenomena at once so varied and so interesting as the Amphibia.

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(T. Bell.)

ANIMAL KINGDOM, an appellation given to that great division of natural bodies to which ANIMALS belong. Like the other kingdoms of nature, the mineral and the vegetable, it is divided into numerous sub-kingdoms, classes, orders, genera, and other subordinate groups, according to the properties and forms of the objects which it comprehends. As the primary grand divisions of the mineral kingdom are founded on the primitive forms of crystallization, and those of the vegetable kingdom on the endogenous and exogenous modes of growth, zoologists have endeavoured to find some common principle for their first divisions of the animal kingdom. The most common function in animals, and in all organized beings, is generation, and we find the animal kingdom divided into four distinct groups by the modifications of this function, viz., *fissipara*, *gemmipara*, *ovipara*, and *vivipara*. But as the fissiparous and gemmiparous modes of generation are effected without the presence of distinct permanent organs, as the fissiparous mode occurs in isolated species belonging to classes remote from each other in the scale, and as nearly all the classes of the animal kingdom belong to the oviparous division, the modifications of this system do not present the means of establishing primary divisions suitable for the purposes of zoology. Although the process of internal digestion is not so universal as the *function* of generation, the internal alimentary cavity is the most universal *organ* of animals, and its forms therefore merit a first consideration in the establishment of primary groups. It is found, however, that in animals whose general structure is nearly the same, the alimentary apparatus varies so much according to the nature of the food, as to render hopeless any attempt to subdivide the animal kingdom from its modifications; as from its having one or two apertures, from its being a simple sac or a lengthened intestine, from its having one, two, or more stomachs or glands developed in its course, or other modifications of this kind.

In the circulating system we are presented with better means for such divisions than in the digestive, for the radiated classes have only vessels for their circulation, the articulated classes have a superadded ventricle, the molluscous classes and fishes a bilocular heart, amphibia and reptiles a trilocular heart, and the birds and mammalia have four cavities in that organ. The respiratory organs likewise afford the means of founding primary divisions, as into ciliated, branchiated, and pulmonated classes, in ascending from the lowest to the highest forms of that system.

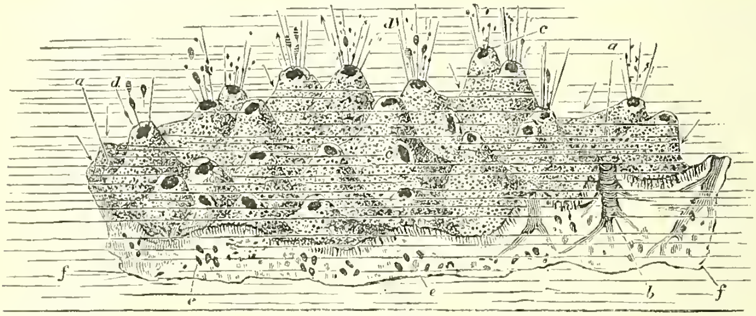
The primary divisions of the animal kingdom adopted by Aristotle, viz., animals with red blood and animals without red blood, are obviously founded on a single principle of classification, and correspond with the more recent divisions of vertebrata and invertebrata; but from the number of distinct classes of animals now comprehended under each of these divisions, they are quite unsuitable as primary groups in the present advanced state of the science of zoology. Considering the functions of the nervous system or the intellectual conditions of animals as a means of classification, Lamarck proposed three great divisions, the lowest of which comprehended the animals regarded by him as *apathic* or automatic, the second the *sensitive*, and the highest the *intelligent*, which, however, are too hypothetical to answer the purposes of the zoologist. Without any fixed principle for the establishment of his primary groups, Cuvier divided the animal kingdom into the *radiated*, the *articulated*, the *molluscous*, and the *vertebrated* divisions, which have been generally adopted by naturalists. From the importance of the nervous system in the living economy of animals, some have sought in its modifications a means of establishing primary or grand divisions of the animal kingdom on principles more uniform and philosophical than those commonly employed. In the radiated or lowest classes of animals, wherever the nervous system is perceptible, as in actinia, medusa, beroe, asterias, echinus, holothuria, &c. it is found in the form of filaments disposed in a circular manner around the oral extremity of the body. This lowest form of the nervous system is expressed by the term *cyclo-neura*, and although, like the radiated and every other character assigned to these classes, it is of partial application, it marks the uniform condition of that system on which the manifestations of life are chiefly dependent, and which principally establishes the relations of animals to surrounding nature. A different form of the nervous system is found in the long cylindrical trunks of the helminthoid and entomoid classes, where we observe almost from the lowest entozoa to the highest crustacea, a double nervous chord or column extending along the whole of the ventral surface of the body. This form of the nervous system, common to the articulated classes of animals, is expressed by the term *diplo-neura*, and it is found to accompany an organization generally more complex than that of the cyclo-neurose classes, and inferior to that of most of the succeeding divisions or sub-kingdoms, especially in the organs of vegetative or organic life, as the vascular, the digestive, and the glandular apparatus. The nervous system is more concentrated around the entrance to the alimentary canal in the molluscous classes, where it generally forms a transverse series of ganglia, disposed around the œsophagus, a character which is expressed by the term *cyclo-gangliata*. The dorsal position of the great ganglia and nervous columns of the cephalopods, and their partial protection by an organised osseous internal skeleton, leads to the condition of the nervous system presented by the vertebrated classes of animals, where its central parts are in the form of a lengthened dorsal nervous chord developed anteriorly into a brain, and protected by a vertebral column and cranium. The vertebrated classes are thus designated *spini-cerebrata*, from the form of the most influential part of their organization.

To the lowest sub-kingdom or cyclo-neurose division belong five classes of animals; viz.,

1. *Polygastrica*, microscopic, simple, transparent, soft, aquatic animals, in which no nervous filament has yet been detected, generally provided with eyes, with a circular exsertile dental apparatus around the mouth, and with vibratile cilia for respiration and progressive motion, and provided with numerous internal stomachs or cœca communicating with the alimentary cavity. (See Polygastrica.)

2. *Porifera*, simple, aquatic, soft, animals, without perceptible nervous or muscular filaments or organs of sense, with a fibrous internal skeleton sometimes supported with silicious and sometimes with calcareous spicula, the body permeated with a soft gelatinous flesh, covered externally with minute absorbent pores, traversed by numerous ramified anastomosing canals, which commence from the pores and terminate in large open vents, as seen in the annexed figure of the *halina papillaris*, Gr. (*fig.* 29), which represents the animal as alive,

Fig. 29.



under water, with the usual currents passing inwards through its pores (*a a*), traversing its internal canals (*b*), and escaping by the larger vents (*c*, *d*.) (See Porifera.)

3. *Polypifera*, aquatic animals, of a plant-like form, generally fixed, of a simple internal structure, for the most part without perceptible nerves or muscles, or organs of sense, and nourished by superficial polypi, which are developed from the fleshy substance of the body, as in the *campanularia dichotoma*, (*fig.* 30), where the irritable fleshy tubular portion of the animal is seen to occupy the interior of the base, the stem, and the branches, and to extend in the form of polypi from the open terminal cells. The polypi of most zoophytes are provided with tentacula around their orifice, as seen at B, (*fig.* 31), and the margins of these tentacula are generally furnished with numerous minute processes, termed *cilia*, (see Cilia,) by the rapid vibration of which, currents are produced in the surrounding water for the purpose of attracting food and of aerating the surface and fluids of the body, as represented in *fig.* 3, A. (See Polypifera.)

Fig. 30.

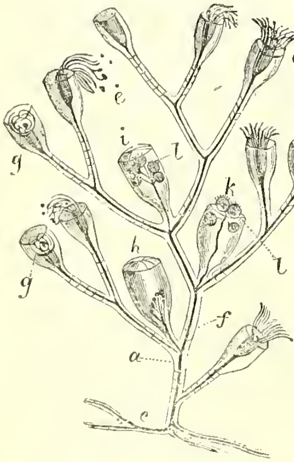
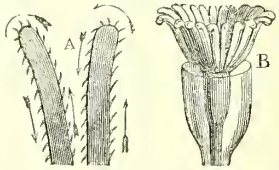


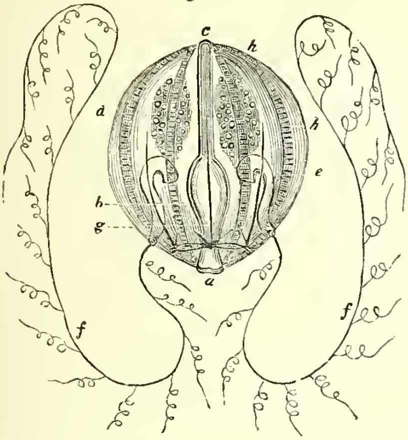
Fig. 31.



4. *Acalephæ*, soft aquatic free animals, of a simple structure, generally of a gelatinous and transparent texture, and emitting an acrid secretion which is capable of irritating and inflaming the skin like the stinging of a nettle, from which the name of the class is derived. They rarely possess a solid skeleton or a perceptible nervous system. They are all marine, often luminous, sometimes they possess eyes with a crystalline humour, they feed on minute floating animals, and swim by the contractions of a highly vascular and irritable mantle or by means of air-sacs, or by the rapid movement of

external vibratile cilia, as in the *beroë pileus* represented in *fig*. 32. This figure represents

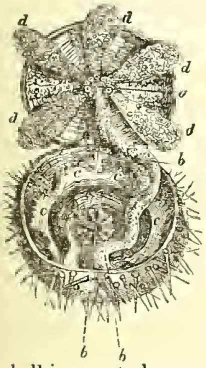
Fig. 32.



one of the ciliograde acalephæ in which the mouth (*a*) is directed downwards, and leads, by a narrow œsophagus, to a wide stomach (*b*), and from this the intestine proceeds straight through the axis of the body to the anus (*c*) at the opposite pole. The longitudinal nerves (*g*), as in *holothuria*, proceed from a nervous ring around the œsophagus. The ovaries (*d*) extend along the sides of the intestine ; the surface of the body is provided with eight longitudinal bands of pectinated broad vibratile cilia (*hh*), and two long ciliated tentacula (*ff*) extend from two curved lateral sheaths. (See Acalephæ.)

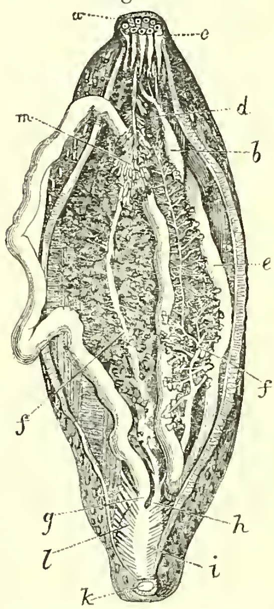
5. *Echinoderma*, simple aquatic animals, for the most part provided with a calcified exterior skeleton or a coriaceous skin, the body for the most part radiated, globular, or cylindrical, often provided with a distinct nervous, muscular, respiratory, and vascular system. These animals have received the names of echinoderma, from the spines or tubercles which generally cover their exterior surface, as seen in the annexed figure of the *echinus esculentus* (*fig*. 33.) The mouth (*b*) is here in the centre

Fig. 33.



of the lower surface, and the intestine (*b,b.*) connected to the shell by a mesentery (*c*), on which vessels are ramified, passes in a convoluted manner upwards to the opposite axis where the anal aperture (*a*) is surrounded by the five openings of the ovaries (*d,d.*) The mouth is surrounded with a maxillary apparatus containing five teeth, and the exterior of the complicated and solid shell is seen to be provided with moveable calcareous spines. These animals are for the most part free, but some are fixed, as the crinoid echinoderma, the vascular system is unprovided with auricle or ventricle, and the digestive canal is seldom furnished with distinct glandular organs. There is sometimes a simple stomach with one aperture and numerous lateral cœca, and sometimes a lengthened intestine with two terminal openings. Some marine animals without an echinodermatous covering are placed in this class from the similarity of their structure in their more essential organs, as is the case with the *holothuria* represented in *fig*. 34. The mouth (*a*) is here surrounded with

Fig. 34.



ramose tentacula (*c*) and an osseous apparatus. The intestine is long, convoluted, vascular, supported by a mesentery, and terminates in a cloaca (*i*) at the opposite axis of the body. The ramified internal branchiæ (*ff*) open from the cloaca ; the great systemic artery receives the aerated blood from the branchiæ, and the organs of generation (*m*) open near the anterior part of the body. The irritable coriaceous skin is supported by five broad longitudinal subcutaneous muscular bands, and five crowded series of tubular muscular feet extend from its surface. (See Echinoderma.)

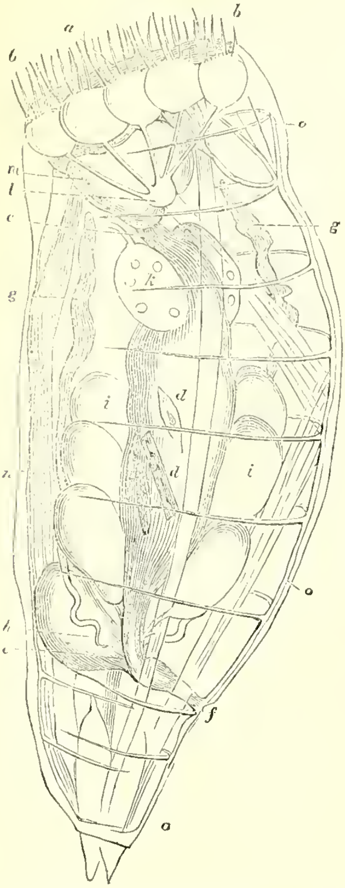
The second sub-kingdom or diplo-neurose division comprehends four classes of helminthoid animals and the same number of entomoid classes, viz.

6. *Entozoa*, parasitic, simple, internal, or fixed animals, for the most part of a lengthened cylindrical form, without distinct organs of sense or any internal skeleton, the mouth or anterior part of the body generally provided with recurved sharp spines, the body generally covered with an elastic white transparent integument, the nervous system seldom distinct, the vascular system without auricle or ventricle, without respiratory organs, and with the sexes generally separate. (See Entozoa.)

7. *Rotifera*, minute aquatic animals with distinct nervous and muscular systems, provided with eyes, lateral maxillæ, a dorsal vessel, an intestine with two apertures, and with vibratile cilia disposed generally in a circular form

around the anterior part of the body. They are termed rotifera from the appearance of revolving wheels produced by the rapid movement of the cilia disposed around the mouth.

Fig. 35.

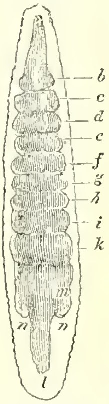


One of these minute wheel-animalcules, the *hydatina senta*, is represented highly magnified in *fig.* 35, where the mouth (*a*) is surrounded with long vibratile cilia (*b b*). The œsophagus (*c*) leads to a capacious stomach (*d*), which becomes a narrow intestine below, opening into the cloaca (*e*), where the genital organs (*i*, *i*, *g*, *g*, *h*,) also terminate. Several ganglia surround the œsophagus, and a dorsal vessel (*o o*) is seen extending along the middle of the back and sending out regular transverse branches. All the rotifera are free, most are naked, many are sheathed or loricated, they exhibit no branchial or pulmonary organs, they are remarkable for their fertility and their tenacity of life. (See Rotifera.)

8. *Cirrhopoda*, aquatic, articulated, diploneurose animals, with articulated cirrhi, and branchiæ for respiration, body covered with a fleshy mantle, and fixed in a multivalve shell. These animals are all marine, the branchiæ are fixed to the bases of the articulated cirrhi, the mouth is provided with mandibles and maxillæ, there is a pulsating dorsal vessel, and a double longitudinal knotted subabdominal nervous chord. The cirrhopoda have been commonly placed among the molluscous classes from the form of their exterior coverings. (See Cirrhopoda.)

9. *Annelida*, with a long cylindrical body generally divided into transverse segments, and covered with a soft skin; the head commonly provided with antennæ and numerous simple eyes, and the mouth with maxillæ; the organs of motion in the form of simple setæ or cirrhi extending from the sides of the body in a single or double row. The vascular system of the annelida consists of arteries and veins, without a distinct auricle or ventricle, and the blood is generally of a red colour. The respiratory organs are generally in form of external branchiæ, sometimes of internal air-sacs, and the alimentary canal passes straight through the body with two terminal openings, and with numerous lateral cœca developed in its course, as seen in that of the leech, *hirudo medicinalis*,

Fig. 36.



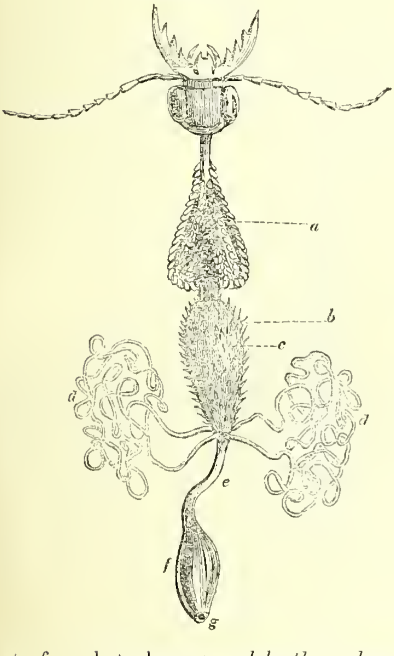
(*fig.* 36.) These lateral cœca (*b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *k*, *m*,) increasing in length and size from before backwards, are often much more lengthened and divided, as in the *halithea*. Many of the red-blooded worms are fixed in calcareous, arenaceous, or other tubes, and many are free and naked. (See Annelida.)

10. *Myriapoda*, with a lengthened articulated body equally developed throughout; the head provided with antennæ and simple eyes; the segments of the trunk free, without distinction of thorax and abdomen; the segments furnished with one or two pairs of articulated legs adapted for progressive motion on land; the respiration is aerial, and performed by tracheæ, which ramify from their commencement in stigmata which open along the whole extent of the body. They do not undergo metamorphosis, nor possess compound eyes nor wings, and they have always more than six pairs of feet. (See Myriapoda.)

11. *Insecta*, with six articulated legs extending from an articulated trunk, which is divided into a head, thorax, and abdomen; the head is provided with a labium, a labrum, mandibles, and maxillæ, with compound and often also with simple eyes, and a pair of antennæ and palpi; the thorax supports the six legs, and commonly one or two pairs of wings, and has attached to it the moveable segments of the abdomen, which embrace the principal organs of digestion, circulation, and generation. The respiration is effected by tracheæ, which form continuous lateral trunks before they ramify through the body. The circulation is aided by a pulsating dorsal vessel provided with numerous valves, and the alimentary canal is furnished with salivary and hepatic, and often with pancreatic glands. The sexes are sepa-

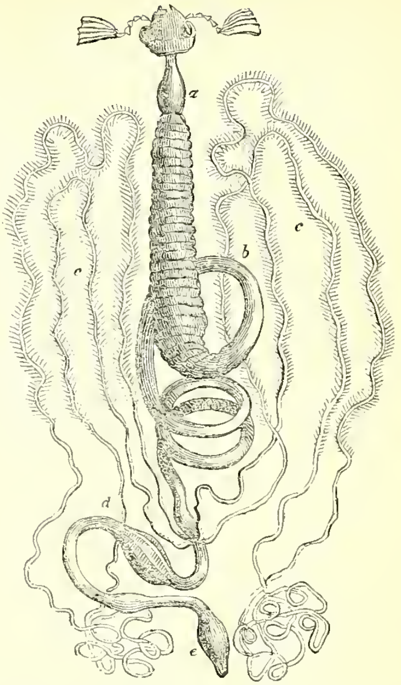
rate, and the genital organs, slow in their development, are highly complicated in the perfect state. These animals generally pass through a series of metamorphoses, and throw off their exuvial covering five or six times during their development. This class is the most numerous in the animal kingdom, comprehending about a hundred thousand species. The greater part of their life is spent in the larva state, during which they are generally most voracious, like the young of other classes. In the adult state the masticating organs and the digestive apparatus vary much according to the kind of food in the different species, as is seen in comparing the alimentary canal of a carnivorous *cicindela campestris* (*fig.* 37.) with

Fig. 37.



that of a phytophagous *melolontha vulgaris*, (*fig.* 38.) In the carnivorous insect (*fig.* 37.) the intestine passes nearly straight through the body with few enlargements in its course, and the glandular organs have a simpler structure. The œsophagus passes down narrow from the head, and dilates into a wide glandular crop (*a*), which is succeeded by a minute gizzard, and this is followed by the chylific stomach (*b*, *c*), which is covered like the crop with minute glandular cryptæ or follicles. At the pyloric extremity of the chylific stomach, the liver, in form of simple biliary ducts, pours its secretion into that cavity by two orifices on each side (*d*). The short small intestine (*e*) opens into a wide colon (*f*), which terminates in the anus (*g*). In the vegetable-eating insect, (*fig.* 38) the alimentary canal is more lengthened, convoluted, and capacious, with more numerous dilatations, and the glandular organs are more developed. The crop (*a*) of the *melolontha* is

Fig. 38.



succeeded by a minute rudimentary gizzard, and to this succeeds a long and sacculated glandular or chylific stomach, which becomes narrow and convoluted below, and terminates in a small pyloric dilatation, which receives the four terminations of the biliary organs. The succeeding part of the intestine is also convoluted, and has three enlargements in its course to the anus (*e*). The liver (*c c*) is here of great magnitude, and has its secreting surface much extended by the development of innumerable minute cœca from its primary ducts. Insects also often present distinct urinary organs, and numerous glands in both sexes connected with the organs of generation. (See Insecta.)

12. *Arachnida*, with the head and thorax united, generally four pairs of legs; without antennæ, or compound eyes, or wings, or metamorphosis; the trunk divided into a cephalo-thorax and abdomen; the head is often provided with two pairs of chiliform manducatory organs; the eyes are simple. The respiration is aërial, sometimes performed by tracheæ, and sometimes by pectinated pulmonary sacs opening on the sides of the abdominal surface of the trunk. In their nervous, respiratory, and circulating systems they indicate a higher grade of development than insects, and like them are generally inhabitants of the land, attaining considerable size and strength, with cunning, cruel, carnivorous habits, and often provided with poisonous instruments. (See Arachnida.)

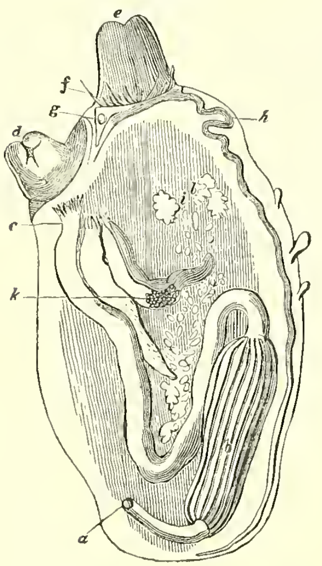
13. *Crustacea*, with the head and thorax generally united, two pairs of antennæ, two

compound eyes, more than four pairs of legs, the respiration effected by gills, and the shell generally hard and calcareous. These entomoid aquatic animals are generally carnivorous, and have a short and straight alimentary canal. Their circulating system is often aided by a muscular ventricle. The sexes are separate, and the organs of generation are double and symmetrical in both sexes. Their biliary organs have a conglomerate form, being composed of minute glandular follicles grouped together into lobules and larger lobes. Some of these animals are fixed and parasitic, and breathe by their general exterior surface; most are free, and respire by means of branchiæ placed under the sides of the carapace or exposed on the under-surface of the post-abdomen. (See Crustacea.)

The third, or cyclo-gangliated or molluscous division of the animal kingdom, comprehends five classes, viz.:—

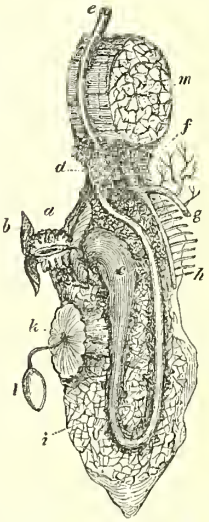
14. *Tunicata*, soft, aquatic, acephalous animals, breathing by internal branchiæ, never in form of four pectinated laminæ, and covered by a close external elastic tunic furnished with at least two apertures. The exterior tunic is lined by a muscular coat; sympathetic ganglia are observed in the abdominal cavity, and the respiratory organs are ciliated as in higher molluscous classes for the production of the respiratory currents. The mouth, unprovided with tentacula or other organs of sense, opens at the bottom of the abdominal cavity, as seen in the *cynthia dione*. (*Fig.* 39. *a.*) The short œsophagus leads to a capacious stomach (*b*), sometimes surrounded by the lobes of a small liver, which pours its secretion into that cavity as in higher mollusca. From the stomach a short wide convoluted intestine proceeds to near the ventral orifice (*d*) of the sac, where it terminates in the anus (*c*). The thoracic orifice (*e*), or the entrance to the respiratory cavity, is generally provided with numerous delicate tentacula (*f*), and a nervous longitudinal filament (*h*) is generally observed to encompass that opening, and to terminate in a small glanglion (*g*). These animals are entirely marine, most are fixed, some are free; they are all female, like the conchifera; the circulation is aided by a muscular heart. Many are organically connected in groups, others are isolated, (See Tunicata.)

Fig. 39.



15. *Conchifera*, acephalous, aquatic animals, covered with a solid calcareous shell, consisting of at least two pieces, and breathing by internal branchiæ in form of four pectinated laminæ. These bivalved animals have the mouth, as in the former class, situated at the bottom of the respiratory or thoracic cavity; the stomach is surrounded and perforated by the lobes of the liver; the circulation is aided by a bifid or a divided auricle and by a muscular ventricle, which is generally perforated by the rectum, as seen in the annexed figure of the organs of the *spondylus*, (*fig.* 40.) The two fimbriated lips (*a*) which surround the mouth are prolonged laterally into four tapering flat pectinated tentacular expansions (*b*). The stomach (*c*) and the intestine are surrounded by the large mass of the liver (*i*), and the rectum, near the adductor muscle (*m*), penetrates the ventricle of the heart (*d*), at some distance from the anus (*e*). The branchial veins (*g*, *h*) return the aerated blood to the two lateral divisions of the auricle, these pour it into the ventricle, by which it is propelled forwards and backwards through the system, so that the heart is here, as in other invertebrated classes, a systemic organ. (See Conchifera.)

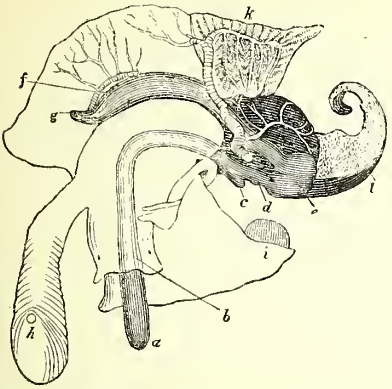
Fig. 40.



16. *Gasteropoda*, body invertebrate and inarticulate, provided with a head which for the most part supports tentacula and simple eyes, and furnished with a muscular foot, extended under the abdomen, and adapted for creeping. These animals are sometimes naked, more generally covered with a univalve, unilocular, solid, external shell. Some gasteropods breathe by a pulmonary cavity, most by branchiæ variously disposed on the surface or under an open mantle. Most are marine, many inhabit fresh waters, and some reside on land. The higher forms are mostly carnivorous, and the lower orders phytophagous, and this difference affects principally their alimentary apparatus,

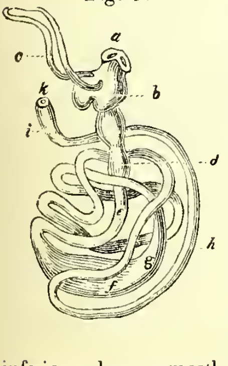
as seen by comparing that of the carnivorous *buccinum undatum*, (*fig.* 41,) with the same

Fig. 41.



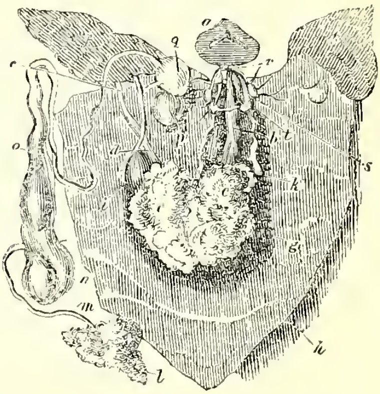
apparatus in the phytophagous *patella vulgata*, (*fig.* 42.) Like most of the predaceous gasteropods the *buccinum* is provided with a long muscular proboscis, (*fig.* 41, *a*, *b*,) capable of being extended to a distance from the mouth, and enclosing a bifid tongue covered with sharp recurved teeth. The œsophagus near the stomach dilates into a small crop (*c*), and to this succeeds a round membranous stomach (*d*, *e*). The whole remaining intestine is shorter than the œsophagus, and dilates into a wide colon (*f*,) before terminating in the anus (*g*), on the right side of the body under the open mantle. The liver, of great size, and accompanying the testicle (*i*) in the turns of the spire, pours its secretion into the stomach as in the acephalous classes. The vas deferens following the right side of the body terminates at the end of the male organ (*h*) in a small tubular styliform duct. In the *patella*, (*fig.* 42,) however, which feeds on marine plants, the mouth (*a*) is provided with a long slender convoluted tongue covered with numerous rows of teeth like a long file. The wide and sacculated œsophagus (*d*) leads to a capacious and lengthened stomach (*f*, *g*), surrounded by the large liver, and the long convoluted intestinal canal (*h*) makes several turns imbedded in the mass of the liver before it arrives at the short dilated rectum (*i*) and anus (*k*). The salivary glands are generally of great size in this class, and present sometimes in the same species both the simple follicular and the conglomerate forms. The pancreas likewise is often present in form of a single follicle opening into the stomach along with the biliary ducts. The inferior orders are mostly male and female, but in the higher forms the sexes are distinct. (See GASTEROPODA.)

Fig. 42.



17. *Pteropoda*, body organized for swimming, mantle closed above, branchiæ external, no muscular foot for creeping, shell, when present, always thin, pellucid, unilocular, and inoperculate. These soft, minute, floating animals are all marine, and are enabled to swim by means of two lateral musculo-cutaneous fin-like expansions, on the surface of which the respiratory branchiæ or vascular plexuses are placed. These lateral fins are never supported by rays. The head is generally provided with retractile or sheathed tentacula, seldom with eyes. The body is sometimes entirely naked, often protected by a delicate thin transparent shell, which encloses the abdomen and is covered with a fold of the skin. They appear to be most closely allied to the inferior testaceous cephalopods in the nature and form of their shells and in their locomotive powers, and also in the general simplicity of their internal structure, especially of their generative organs. The structure of one of the naked pteropods, *clio borealis*, is represented in *fig.* 43, where the abdominal cavity is exposed by the mantle

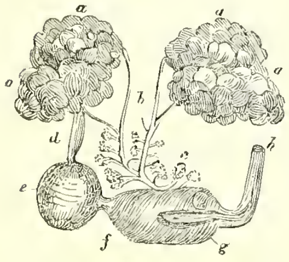
Fig. 43.



being opened from behind. The mouth (*a*) leads to a long œsophagus (*b*), which is surrounded by a circular series of nervous ganglia (*t*). The stomach (*c c*) is imbedded in the lobes of the liver (*g*), which open by numerous short ducts into its cavity. The œsophagus is accompanied by the two long simple salivary follicles (*k*), and at the left or pyloric extremity (*d*) of the stomach is placed the heart (*i*), enclosed in its pericardium, which receives the arterialized blood from the branchial veins, and sends it through the system. The bottom of the abdomen or cavity of the mantle (*h*) is occupied as in the cephalopods with the generative organs, which consist of an ovary (*l*) and long oviduct (*m*, *o*), into which a short wide cœcum (*n*), commonly considered as a testicle, pours its secretion. The oviduct terminates on the left side, near the anus (*e*), in a small glandular sac (*q*), beneath which is the rhenal sac (*p*). The pteropods are commonly found floating in immense numbers at the surface of the water in still warm evenings in tropical seas; some, as the *clio borealis*, figured above, abound in the Arctic seas. (See PTEROPODA.)

18. *Cephalopoda*, free cyclo-gangliated or mulluscous animals, with the feet disposed around the head, respiring by internal branchiæ, and with the abdominal cavity enveloped by a muscular mantle open anteriorly. The cephalopods are all marine animals capable of swimming by means of membranous or muscular expansions, which are never supported by rays. The surface of the body is often naked, sometimes covered with a shell, which is generally polythalamous, rarely monothalamous, and always inoperculate. There is often a concealed, loose, dorsal, calcareous or horny shell contained in a shut subcutaneous sac. The mouth is furnished with two horny or calcified mandibles, and the rudiments of an internal organized cartilaginous cranium and vertebral column are generally perceptible, together with some detached parts of the skeleton of vertebrata. The œsophagus is surrounded by a nervous collar, from which two supra-abdominal nervous columns generally extend along the middle of the back, and sympathetic ganglia are observed in the abdominal cavity as in the inferior molluscous classes. These are predaceous animals, and the alimentary canal, though generally furnished with three enlargements, forming a crop, a gizzard, and a spiral or proper chylific stomach, is always very short. There are two pairs of salivary glands; the liver is of great size, and pours its secretion, with that of the pancreatic follicles, into the stomach, as in the inferior classes. There is always a strong muscular systemic ventricle, and generally a divided auricle placed at the beginning of the branchial arteries. The common form of the chylopoietic organs is seen in those of the *loligopsis guttata*, (*fig.* 44,) where the liver (*a a a a*) pours its secretion by ducts (*b*), which are surrounded and penetrated by the pancreatic follicles (*c c*), and which unite into a single canal before they open by a valvular aperture into the third or chylific stomach (*f g*). The crop (*d*) ends in the strong muscular gizzard (*e*), and from the third stomach (*f g*) the short intestine (*h*) ascends in front of the liver to terminate by a valvular anus at the base of the funnel. The naked species have a glandular sac for secreting a black inky matter, which appears to be wanting in those protected by an external shell, excepting in the argonauta, where the shell is seen in the ovum, and where there is a slight membranous connexion between the animal and its thin delicate calcareous covering. The sexes are generally separate, but the lowest foraminiferous cephalopods appear to approach to the pteropods in the male and female character of the genital organs. (See CEPHALOPODA.)

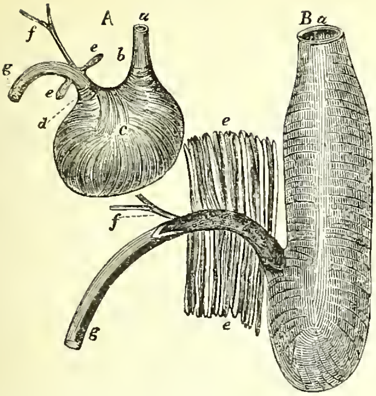
Fig. 44.



The last or highest DIVISION of the animal kingdom, comprehending the vertebrated or red-blooded animals, or SPINI-CEREBRATA, consists of five distinct classes, characterised chiefly by their generative, their sanguiferous, and their tegumentary organs, viz.—

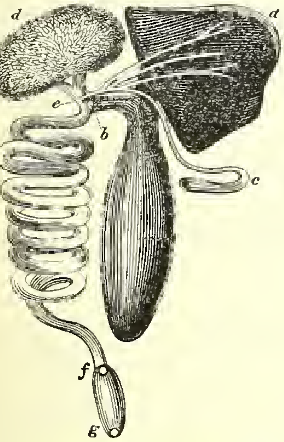
19. *Pisces*, cold and red-blooded oviparous vertebrated animals, with one auricle and one ventricle to the heart, breathing by permanent branchiæ, and with fins for progressive motion. They have a vertebral column and cranium, enclosing a spinal cord, and brain consisting of a medulla oblongata, optic lobes, cerebral hemispheres, olfactory tubercles, and a cerebellum. The hands and feet are always formed like fins for progressive motion in a watery element. The fins are supported by rays prolonged from the skeleton, the body is generally covered with scales, the trunk is organized for the lateral motion of the tail, there is no sacrum, and the pelvic arch is unconnected with the vertebral column. The bones are elastic or cartilaginous, and the centres of ossification for the most part remain permanently detached. The bodies of the vertebræ terminate in two cup-like cavities, they move on elastic tense intervertebral sacs, and the transverse processes are directed vertically downwards in the coccygeal region of the skeleton to facilitate the lateral motion of the trunk. The muscles, of a white colour, are disposed in oblique strata on the sides of the trunk for the movement of the elastic vertebral column. The mouth, destitute of salivary glands, is generally furnished with numerous unequal, irregular, fangless, osseous teeth, and the wide œsophagus, short like the neck, leads to a capacious stomach, from which the intestine, shorter than in the higher classes, and nearly equal throughout, proceeds, without cœcal enlargement, to terminate in a cloacal sac on the inferior surface of the trunk. The liver is large, and pours its secretion generally by a single duct into the duodenum, near the pyloric extremity of the stomach and close to the opening of the pancreatic duct, as shown in the annexed figures of these parts in the frog-fish (*fig.* 45, *A*) and the cod (*fig.* 45, *B*). The œsophagus (*a*) of the frog-fish (*fig* 45, *A*) leads to a large globular stomach (*c*) with a strong muscular cardiac sphincter (*b*). The pyloric extremity is also surrounded with strong muscular bands (*d*), and beyond its pyloric valve two pancreatic simple glandular follicles (*e e*) open into the duodenum (*g*) close to the opening of the ductus communis choledochus (*f*). In the cod (*fig.* 45, *B*) the wide œsophagus (*a*) leads to a long and capacious muscular stomach shut below, and immediately beyond the pyloric valve, formed by a circular fold of the mucous coat, open the ducts of numerous straight and simple pancreatic folli-

Fig. 45.



cles (*e e*) along with the ductus communis choledochus (*f*). The cartilaginous plagiostome fishes, the most complicated of this class, have a conglomerate form of the pancreas opening in the same situation. In the sturgeon and in the sword-fish an intermediate form is seen between the simple pancreatic follicles of the invertebrated classes and the more complicated conglomerate organ in the higher vertebrata. This is shown in the annexed figure of the chylopoietic viscera as I found them in the *xiphias gladius* (*fig.* 46), where the liver (*a*) is raised up to show

Fig. 46.



the three hepatic ducts uniting with the cystic from the curved gall-bladder (*c*) to form a very short ductus communis choledochus. The pancreas (*d*) forms a large reniform mass composed of numerous straight follicles produced by the successive divisions of the great terminal duct (*e*) of this organ. This large intermediate organ is surrounded with a distinct muscular tunic to force its contents into the duodenum immediately beyond the pyloric valve (*b*). The tortuous small intestine ends by a valvular orifice (*f*) in a very short but distinct colon, which presents no cœcum in its course to the anus (*g*). The bilocular heart of fishes is entirely branchial; it is often preceded by a *sinus venosus*, and is always succeeded by a *bulbus arteriosus*, which often presents numerous internal valves in its course. The venous blood is entirely sent through the gills, and the branchial veins, after giving branches to the anterior parts, unite to form the aorta which sends the arterialised blood through the rest of the system without the aid of a systemic heart. The respiration is effected by the transmission of water through the mouth or through distinct spiracula, and over the surface of the branchiæ, which are internal in the adult, and are often preceded by external branchiæ in the young. The lungs are always rudimentary, when present, sometimes in form of a shut single air-bag, sometimes divided or ramified, and most *generally communicating* by a *ductus pneumaticus* with the intestine or stomach, or œsophagus, but seldom employed for respiration. Fishes are oviparous and have the sexes separate; the ovaries are continuous with the oviducts in osseous fishes, and detached from them in the plagiostome chondropterygii, and impregnation sometimes takes place internally and sometimes after the ova are separated from the body. (See Pisces.)

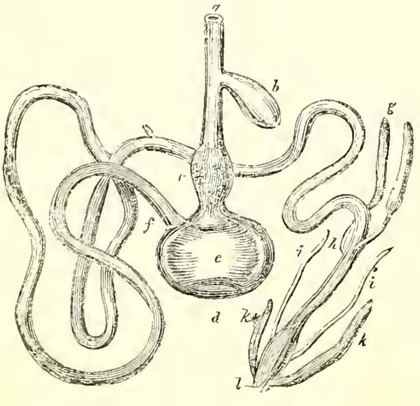
20. *Amphibia*, cold and red-blooded, vertebrated, oviparous animals, with three cavities of the heart, with a naked skin, and breathing, in the young state, by gills. These animals commence their career like fishes with one auricle and one ventricle, which send the whole of the blood through the branchiæ, and they have at this period also double concave bodies of the vertebræ, as in fishes. Many retain the gills through life, accompanied with pulmonic cavities, from which the arterialised blood is sent to a small left auricle. These animals are termed *amphibia* from the metamorphosis to a terrestrial from an aquatic life seen in most of the species. Their skeleton is imperfectly consolidated, their ribs very short or wanting, their pelvic arch free or nearly so, and their atlantal and sacral extremities often very imperfectly developed or partly deficient. Their toes are destitute of claws, as their skin is of scales, and the respiration through their naked, highly sensitive, and secreting surface compensates for the imperfect development or limited use of their lungs, especially during submersion or hybernation. Some reside constantly in the water, others occasionally, and others continue on land. The male organ of intromission is rarely developed, and impregnation of the ova is generally effected externally. The genital organs are double and symmetrically developed in both sexes. The perennibranchiate amphibia, especially the axolotl, have been shown by Weber to possess a double auricle like the caducibranchiate species. (See Amphibia.)

21. *Reptilia*, cold and red-blooded, oviparous, vertebrated animals, with two auricles and one ventricle, not breathing by gills in their young state, covered with scales, and with the means of internal impregnation. These animals, whether aquatic or terrestrial, breathe only by means of lungs, and their pulmonic respiration and the left auricle of the heart are

greater than in the amphibia. Their bones are more consolidated than in the lower vertebrata, their pelvic arch, when developed, is more firmly attached to the vertebral column, the centres of ossification, especially of the cranial bones, generally remain detached, the extremities are for the most part more competely developed, and the toes are generally provided with claws. Their cerebellum is remarkably small, their muscular irritability languid, and they have great tenacity of life. This ventricle, which receives both the venous and arterialised blood, is more or less divided by an ascending imperfect septum. The thoracic and abdominal cavities are not separated by a muscular diaphragm, and the lungs extend backwards over the abdominal viscera. Their organs of generation are double in both sexes, and symmetrically developed on the two sides of the body. The two portions of the corpus cavernosum are often detached and bifid; the chorion of the ova is generally thin or coriaceous, seldom calcified or hard, and the instincts of the parent generally extend to the protection of the young. (See Reptilia.)

22. *Aves*, warm and red-blooded, oviparous, vertebrated animals, with four cavities of the heart, covered with feathers, and with their arms organized for flight. Their bones are the most compact and dense in texture, the most extensively anchylosed, and generally contain air admitted from the cells of the lungs. Their tympanic bone is moveable, they have horny mandibles in place of teeth, their coracoid bones reach the sternum, the sternal ribs are ossified, and they want the tarsal bones. Their diaphragm never forms a complete partition between the thoracic and abdominal cavities. The hemispheres of the brain are without convolutions, the optic lobes are large and hollow, the cerebellum is large and sulcated, and the posterior enlargement of the spinal chord of great size. The great irritability of their muscular system corresponds with the great extent of their respiration, the high development of their nervous system, the rapidity of their circulation, and the increased energy of all their functions. Their alimentary canal is furnished with a crop, a glandular infundibulum, a gizzard, and generally with two cœca-coli, as seen in the annexed diagram (*fig.* 47), showing the

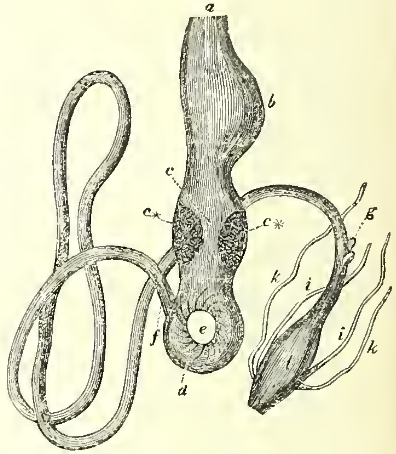
Fig. 47.



common form of these parts in a gallinaceous bird. In these gallinaceous birds the œsophagus (*a*) sends out at a right angle with its course a large crop (*b*), with a contracted neck, and supplied with glandular follicles. Beneath this is the infundibulum or glandular stomach (*c*), with numerous large follicles placed between the mucous and muscular coats, and this opens into the large muscular gizzard (*d*), provided externally with two strong digastric muscles (*e*). The cardiac and pyloric orifices of the gizzard are close to each other (*f*), and towards the lower part of the small intestine a minute cœcum often indicates the original entrance of the yolk-bag. The two long cœca-coli (*g*) commence by narrow entrances (*h*), and the short colon ends in a common cloaca (*l*) for the genital and urinary secretions.

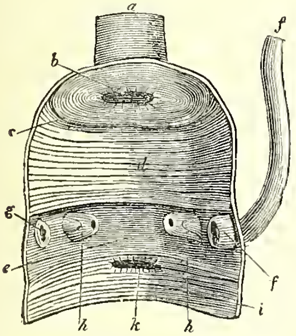
In the predaceous birds, as the eagles (*fig.* 48), the œsophagus (*a*), the crop (*b*), the infundibulum (*c*), and the gizzard (*de*), are capacious, thin,

Fig. 48.



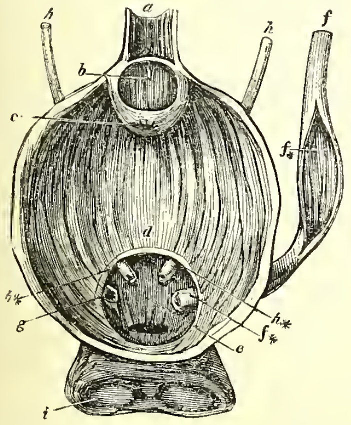
and membranous, and form a continuous cavity for the prey, from which the indigestible parts can be thrown out in a bolus. In these birds the cœca-coli (*g*) are very small, sometimes unequal, or wanting. The urinary (*ii*) and genital organs (*kk*) enter the cloaca (*l*) near the anus. The right ventricle of birds has the tricuspid valve in form of a thick strong muscular fold, and the aorta descends on the right side. The lungs form two undivided, light-coloured lobes, fixed by pleuræ to the back part of the trunk, the last rings of the trachea form an inferior larynx, the bronchi pass in a membranous form through the lungs, and the lungs open into large membranous abdominal air-cells, which communicate with the interior of the bones. This extensive aeration of their systemic as well as their pulmonic vessels gives energy to their muscles for their aerial life and their distant migrations, and a high temperature to their body for the incubation of the egg. Their plumage and their downy covering are the best suited for their aerial life and their high internal heat. Their organs of generation are double and symmetrical in the male, and generally unsymmetrical in their development in the female. The testes are internal, and the vasa deferentia terminate in the cloaca, where there is sometimes a grooved organ of intromission. In the female the left ovary and oviduct are developed, the right for the most part atrophiated and useless. The cavity of the cloaca in most birds, as seen in that of the great *condor* of the Andes (*fig.* 49), receives the end of the rectum (*a*), which forms a wide

Fig. 49.



rectal vestibule (*b*): beneath this lies the part analogous to the urinary bladder (*c d*). Lower than the urinary sac are found the two openings of the ureters (*h h*), with the pervious oviduct on the left side (*f*), and the remains of the impervious oviduct (*g*) on the right side. The *bursa Fabricii* and the clitoris (when present) are placed more posteriorly in the preputial cavity. The most distinct forms of these generative and urinary parts, and the nearest approach to the mammalia are seen in the cloaca of the ostrich (*fig.* 50), where the rectum (*a*) opens into a wide and distinct rectal vestibule (*b*), which extends into a large urinary bladder (*d*). Beneath the urinary bladder is the urethro-sexual canal (*e*), into which the two ureters

Fig. 50.



(*h h h* h**) and the oviducts (*f f* f* g*) open towards the dorsal and lateral part. The preputial cavity (*i*) is the terminal portion in which the distinct clitoris is here lodged. The ova are impregnated internally, their chorion is calcified, and their development is effected by incubation. (See Aves.)

23. *Mammalia*, warm and red-blooded vertebrata, having four cavities of the heart, with a viviparous mode of generation, and possessing mammary glands; with the lungs free in a distinct thoracic cavity, and generally having the body more or less covered with hair. The bodies of their vertebræ unite by flat surfaces, the tympanic bone is fixed, the jaws are generally furnished with teeth lodged in deep alveoli, the coracoid bone rarely reaches the sternum, and the posterior extremities, when present, are always attached by the pelvic arch to a solid sacrum. The thoracic and abdominal cavities are separated by a muscular diaphragm. The hemispheres of the brain contain large ventricles, and rarely want convolutions, the optic lobes are small, concealed, solid, and divided by a transverse sulcus, the commissures of the brain and cerebellum, and the hemispheres of the cerebellum are large. The alimentary canal is of great length, the colon long and wide, with a single cœcum, and sometimes with a vermiform appendix, and the anal opening is generally distinct from the urinary and genital passages. The tricuspid valve is thin and membranous, the aorta descends on the left side, there is no inferior larynx, the epiglottis is distinct, and the bronchi continue cartilaginous into their ramifications in the lungs. The lungs, generally divided into lobes, move freeely in a distinct thoracic cavity, and have no abdominal cells or perforations on their surface, as in birds. There is always a urinary bladder, and the urethra in the male passes through a tubular penis. The organs of generation are double in both sexes, symmetrical in the male, and rarely unsymmetrical in the female. The oviducts commonly unite at their lower part to form a uterus, in which the ovum becomes again connected with the parent, and is hatched. There are mammary glands opening externally for lactation during the helpless condition of the young. (See Mammalia.)

These are the primary and secondary divisions of the animal kingdom, the structure, classification, and history of which it is proposed to consider in this Cyclopædia, under the heads of the several classes as enumerated in the subjoined table.

ANIMALIA.

I. Sub-regnum, Cyclo-neura vel Radiata.
- Classis 1. Polygastrica.
- 2. Porifera.
- 3. Polypifera.
- 4. Acalephæ.
- 5. Echinoderma.

II. Sub-regnum, Diplo-neura vel Articulata.
- Classis 6. Entozoa.
- 7. Rotifera.
- 8. Cirrhopoda.
- 9. Annelida.
- 10. Myriapoda.
- 11. Insecta.
- 12. Arachnida.
- 13. Crustacea.

III. Sub-regnum Cyclo-gangliata vel Mollusca.
Classis 14. Tunicata.
15. Conchifera.
16. Gasteropoda.
17. Pteropoda.
18. Cephalopoda.

IV. Sub-regnum Spini-cerebrata vel Vertebrata.
Classis 19. Pisces.
20. Amphibia.
21. Reptilia.
22. Aves.
23. Mammalia.

For the BIBLIOGRAPHY of this article see that appended to each of the articles on the classes of animals and COMPARATIVE ANATOMY (*Introduction.*)

(*R. E. Grant.*)

ANIMAL (from anima, breath, the living principle. Lat. *animal.* Gr. *ζῶον.* Fr. *animal.* Germ. *Thier.* Ital *animale*). The objects of the material universe were long considered as arranging themselves naturally into three grand divisions, or *kingdoms*, as they were called: the animal, the vegetable, and the mineral. Closer attention, however, and a more careful study of the qualities and actions of the various bodies composing these kingdoms, lead to the conclusion that two of them have much in common, and consequently that a two-fold division suffices to comprehend the whole of the objects in nature,—these are the inorganic, or lifeless, and the organic, or living; the first embracing minerals, fluids, gases, or the various forms in which simple brute matter presents itself to our observation; the second including vegetables and animals.

As the subject ANIMAL may be regarded in the light of the very kernel and epitome of the entire matter treated in the pages of our Cyclopædia, we shall give such extension to this head as its importance seems to demand, studying brevity nevertheless, and embracing in general views the particular points which will be illustrated in detail in the different articles on anatomy and physiology, human and comparative.

COMPARISON OF THE ORGANIC AND INORGANIC WORLDS.

Physical qualities and elementary composition of unorganized and organized bodies.—The organic and inorganic kingdoms of nature are distinguished from one another by many strong features of difference,—first, in reference to their general physical qualities, external form, volume, and elementary composition; and second, in regard to their capacities of action.

The *forms* of the objects composing the inorganic world, indeterminate when they are considered in their masses, are reducible to a very few simple crystalline shapes when they are regarded in their parts. The cube, the hexahedron, the rhomb, the prism, &c. are the elementary forms of the inorganic world: plane surfaces and straight lines uniting under different inclinations, and originating angles that measure certain determinate numbers of degrees are the *accidents*, which give them their characteristic and individual shapes.

But the inorganic world has not absolutely even this limited perfection of form, if the expression may be allowed. In order that the objects which compose it may exhibit themselves under the form of crystals, solution of some kind, rest, time, and space are required; and these or any of these being denied, the objects of the unorganized world present themselves or exist as simple aggregates of molecules, shapeless in their component parts as in their masses. And further, even when the objects of the inorganic world do present themselves under definite forms, these are not necessary and invariable. Carbonate of lime, to take a single instance, occurs crystallized not only in rhombs, but in hexahedral prisms, in dodecahedrons, the several faces of which are pentagons, in solids terminated by twelve triangles with unequal sides, &c. In their material composition, too, unorganized bodies are essentially homogeneous: one part of a mineral does not differ from another.

This is very different from what occurs in the world of organization. From the lowest to the highest of living beings the shape is determinate for the individual, not only as a whole, but even as each of its component parts is concerned. Instead of being circumscribed within angles and right lines like the objects of the inorganic kingdom, those of the organic are mostly rounded in their forms, or they are branched, or articulated and made up of several parts, which present varieties of conformation in harmony with the kinds of offices they have to perform, or the conditions surrounded by which the beings thus fashioned exist. Neither do they consist of homogeneous particles like minerals, but are made up in general of heterogeneous parts: in plants we have roots, leaves, branches, flowers, &c.; in animals muscles, nerves, bones, and a great number of organs besides, each itself reducible to a variety of simpler parts or elements, entitled tissues.

The organic world also presents an immeasurably greater variety of forms than the inorganic: the myriads of animals and vegetables that people and possess the earth differ to infinity from each other in their forms and physiognomies.

Size.—Neither is there less discrepancy between the inorganic and the organic world in the quality of size, which, in the first, is perfectly indeterminate, being greater or less, simply as the constituent molecules happen to be aggregated in larger or in smaller numbers. The volume of organized bodies, on the contrary, is determinate; every animal, every vegetable, has a particular stature, a certain bulk, which is that of its species also, and is within narrow limits alike in regard to all the individuals composing the kind.

Composition.—Contrasted in their chemical nature, organized and unorganized bodies present numerous and striking points of dissimilarity. Modern chemistry enumerates no fewer than fifty-two elementary or simple substances,* besides the imponderables — light, caloric, and electricity. The whole of these are met with in the mineral or inorganic world; but no more than nineteen of them have been detected in the constitution of organized bodies.† Six of this number, indeed,—oxygen, hydrogen, carbon, azote, phosphorus, and calcium, occur in such abundance as to compose almost the whole mass of organized bodies; the remaining thirteen are met with but sparingly distributed, and some of them even appear to be adventitious, and by no means essential to the constitution of the bodies in which they are encountered.

Speaking generally, the chemical composition of inorganic objects may be stated to be the more simple, many of them consisting of a single element only, and when more compound generally presenting binary, and at most ternary combinations of known elements. Organized bodies, on the other hand, are never made up of single elements, they are not even binary combinations, vegetables in the aggregate being at least ternary, and animals at least quaternary compounds. Though the elements which compose inanimate objects, therefore, are more numerous, the combinations they enter into are less complex than those they form in the constitution of living things.

Another difference in the chemical constitution of unorganized and of organized bodies consists in the *mode* or *form* in which the chemical elements exist in each. In the former they present themselves *immediately* as it were, the chemist in his analyses coming upon them at once; in the latter they occur under two forms, the one immediate as in minerals, the other *mediate*, or arrauged under a variety of new and peculiar shapes, which, with reference to the bodies they mainly constitute, are conveniently and fairly spoken of as *elements*, with the prefix organic, they being exclusively the products of life and organization; these are also frequently spoken of as the *immediate principles* of vegetables and animals.

In the inorganic world, again, the constituent elements of bodies are always united by virtue of, and in harmony with, the general laws of chemical affinity, whilst in the organic the compounds formed are very often even the opposites of those that would have been originated under the dominion of these laws. From this it comes that, whilst the chemist finds almost as little difficulty in recomposing as in disintegrating inorganic objects, he has hitherto failed in compounding any one of the higher organic products or immediate principles of plants and animals.* Chemical analysis we may therefore imagine to be a process of a very different nature as applied to inorganic objects from what it is when applied to organic substances. With reference to the former it signifies a simple disintegration, with an inherent capacity in the elements separated to reunite into the compound analysed; in the latter it constantly implies destruction, without any such continuing power of recombination among the constituent elements. Chemical synthesis, consequently, is an expression that can only be logically used in connection with inorganic objects.

Considered with reference to their intimate texture, organized beings are no less strikingly different from unorganized bodies. The last are either solid, or fluid, or gaseous; they never occur commingled, each subserving the existence of the other. The water of crystallization, and the globules of this and other fluids occasionally found included within the substance of minerals, are but adventitious, being in the first instance entangled among their component molecules, in the second imprisoned within accidental cavities in their substances but contributing in nowise to the existence or duration of the matter that surrounds them. Organized bodies, on the other hand, consist uniformly of solid and of fluid parts: whilst the vegetable has its woody fibre and constituent parenchyma, it has its sap also; and animals with their firmer bones, muscles, cellular substance, &c. have likewise blood circulating through their bodies, or various fluids deposited within their tissues, which are just as essential to their constitution and continuance as the containing parts themselves. It is even by the mutual play of the solids and fluids which enter into the composition of organized beings that they manifest themselves in action or exhibit the phenomena which are peculiar to them, and which we denominate vital. It were indifferent whether we took away the solids (were such a thing possible) or the fluids of a vegetable or an animal; in either case it must perish. The solids and fluids of organized beings consequently are in intimate and inseparable relationship one with another.

Consistence.—From this admixture of solids and fluids in the world of organization results the variety of *consistence* which its objects present. In the inorganic kingdom, *rigidity*,—rigidity, too, which is uniform,—is one of the distinguishing characteristics. In the organic, on the contrary, *pliancy* and *softness*, which vary as well in every individual as in almost

* Oxygen, hydrogen, carbon, phosphorus, sulphur, borium, silenium, iodine, fluor, chlorine, bromine, azote, silicium, zirconium, aluminium, yttrium, glucynium, magnesium, calcium, strontium, baryum, potassium, sodium, lithium, manganese, zinc, iron, tin, arsenic, molybdenum, tungsten, columbium, chromium, antimony, ciranium, cerium, cobalt, titanium, bismuth, cadmium, copper, tellurium, lead, mercury, nickel, osmium, silver, gold, platinum, palladium, rhodium, and iridium.

† Oxygen, hydrogen, carbon, azote, phosphorus, sulphur, iodine, bromine, chlorine, fluor, silicium, aluminium, magnesium, potassium, sodium, calcium, manganese, iron, and copper.

* The exceptions to this position are scarcely worth noticing—one or two of the more simple organic elements, oxalic acid and urea, for example, have been formed synthetically, and a substance bearing a remote affinity to fat has also been produced. No one, however, has ever succeeded in forming fibrine, neurine, fecula, gum, &c. synthetically.

every part of the same individual, are no less strongly marked and inherent features. Solidity or hardness may be looked upon as the term of perfection of a mineral; softness, on the other hand, often appears to be the term of perfection among vegetables and animals, the parts in these being generally softer in proportion as they have more important or noble offices to perform. The tender fibrils of the root, the leaves, flowers, stamina and pistilla in plants; the brain, vessels, viscera, &c. in animals, are softer than the bark and woody fibre, than the bones, ligaments, skin, &c. which form, as it were, but the frame and covering of the proper fabric. This quality also varies in the organic world according to the age of the individual: the nearer any organized being is to its birth or origin, the softer will it generally be found to be; the longer it has lived, the harder will it as uniformly be ascertained to have become. Many organized beings, indeed, in the first stages of their existence, are wholly fluid; they only acquire consistence as they are evolved and approach maturity.

It is almost needless to speak of the extent to which inorganic bodies differ from organic in these respects; they are rigid and hard in all their parts alike, and never vary in consistence from the moment of their formation to that of their disintegration or decomposition.

The *elementary particles* or *molecules* entering into the composition of organized and unorganized objects, also differ in their essential nature. All organized beings, in fact, whether their solids or fluids are regarded, appear to be made up of or to contain globular or oval and sometimes flattened corpuscles. The simplest plants,—the confervæ, tremellæ, &c., and the simplest animals,—the infusoria, polypi, &c., are alike composed of globules and a fluid; nor is the case different as regards the most complicated vegetable or animal that exists. The elementary globule has now been discovered in almost all the solids and fluids both of vegetable and of animal bodies,—in the sap and cambium or succus proprius of vegetables, and in the blood, chyle, milk, and other fluids of animals; in the fecula, albumen, parenchyma of the leaves, cells of the flowers, &c. of plants, and in the cellular membrane, muscle, brain, nerve, gland, &c. of animals.

Nothing of the same kind has yet been detected among inorganic bodies. Angular particles separable to infinity into others of a like description are the elements of composition in minerals.

Globules, then, are to be regarded as the elementary constituents of organized bodies, as the ultimate molecules possessing a distinct form, which by their aggregation compose them. The first step, indeed, in the singular process by which infusory animals are eliminated during the decomposition of organized substances, is the formation of globular corpuscles; these, by their subsequent aggregation in some cases and individual evolution in others, appear to give birth to the organized atoms that by-and-by make their appearance; and, as we have said, globules are now admitted to form the basis of the different tissues which enter into the composition of the very highest among animals. These various tissues, in fact, would seem to result from the different modes in which the elementary globules are disposed; and it is not improbable that the difference of function they exhibit may yet be found in harmony with, and perhaps depending on, peculiarity of arrangement in their constituent molecules.

This aggregation of the organic molecules into a variety of tissues and peculiar organs forms another essential feature of difference between the organized and the unorganized world. Minerals, indeed, as they manifest no variety of phenomena analogous to those of life, required no diversity of elementary constitution in their different parts; they are consequently homogeneous. In minerals the component molecules are arranged in layers placed one upon another, so that their crystals can be readily cleft in a variety of directions, according to the elementary arrangement of these. In vegetables and animals, on the other hand, the constituent molecules always form tissues, the fibres of which interlace or cross one another; in no living or organic thing do we observe aught similar to what is called the cleavage in minerals.

From this it comes that minerals are as complete in their parts as they are in their masses: the minutest spark of carbonate of lime has all the properties of a crystal of this substance, were it as large as a mountain. The case is very different in regard to organized beings; these consist of a number of organs, the sum of whose actions constitutes the peculiar vitality of each being, and no individual part or organ enjoys capacity to manifest itself abstractedly from the system to which it belongs. All the parts of organized bodies are mutually enchained by bonds of the strictest causality; this even follows necessarily from the manner in which they originate and are evolved. The radicle that bursts from the fecundated seed of a plant determines the growth of the stem, which subsequently and in its turn plays the same part with reference to the leaves and flowers,—the parts that appear first are the cause of the appearance of those that follow at later stages. No relation of this kind exists among inorganic bodies. When a crystal is formed in the midst of a fluid, the particles composing it unite, in conformity with the mere laws of cohesion and affinity, not in consequence of any determining influence in the particles which cohered the first,—each stage or period of the process of crystallization is independent of that which preceded it. Whilst the parts of an inorganic body, therefore, can exist with all their qualities, as well in a state of disintegration as in one of aggregation, the component parts of organic bodies can only exist with their distinguishing properties when united to the entire being. Individuality in the organic world, far from existing in the integral molecule as it does in the inorganic, can only be said to exist in the mass of integral molecules united into that congeries of organs which constitutes a particular being. As a consequence of this independence on the one hand, and dependence on the other, we find, that whilst in the inorganic world the several parts may be modified without the others feeling the influence of the change induced, in the organic, implication of one part and modification of one action are communicated to and manifested in the state and actions of all the other parts.

Considered with regard to their *duration*, the objects composing the organic and the inorganic world differ essentially. In the former this period is determinate and definite, and, although it varies greatly, it depends in a great measure on circumstances inherent in the individuals; in the latter it is indeterminate and indefinite, and when the objects composing it cease to be, it is generally in consequence of circumstances exterior to themselves. Organized beings exist for a limited time and in opposition to many of the physico-chemical laws; unorganized beings exist indefinitely, and only in harmony with the whole of these laws. Organic beings continue to exist in consequence of a kind of reciprocal action with external things, and especially by virtue of an incessant change and renewal in their constituent elements. The very condition of existence of an unorganized body is quiescence; any new action between its molecules themselves, or between these and others external to them, any addition to, or subtraction from, its component parts, implies the destruction of its individuality.

In the organic world, new forms result from the actions of forms already existing, which have the wonderful property of producing others similar to themselves; and this in virtue of no general physico-chemical law, but of an especial power inhering in each organized being individually. There is nothing like this faculty of *procreation* or of *generation* in the inorganic world. When a crystal is produced, it is necessarily at the expense of one or of others that have already existed, or of a combination of the elements of these; destruction is here a necessary preliminary to production, and the process is simply one of *re*-formation, not of *genesis* or creation. Neither in the *re*-formations of the inorganic world do we find that the forms are always necessarily the same as those which preceded them: the crystalline form does not depend on the nature of the integral molecules, but on their mode of aggregation and number. In the organized world, again, nothing is more certain and fixed than that the form of the new being shall resemble that which gave it birth.

The last distinction we shall mention under this head of material composition and physical qualities between organic and inorganic bodies is, perhaps, less striking, though not less interesting on that account: it is this,—that whilst in inorganic bodies the composition is quite determinate, in organised beings, although constituting particular species, the composition may present individual differences or modifications. These are designated by the titles *temperament, constitution, &c.* There is no corresponding modification recognizable in the inorganic world.

From what has now been said, it appears that organized and unorganized bodies differ essentially from one another in their general physical qualities and material constitution. The form of the organized being is determinate, and its outline is rounded or undulating; its size is limited; its duration is temporary; its composition is an assemblage of heterogeneous parts, of solids and fluids, arranged so as to compose a variety of fibrous and cellular tissues, and aggregates of *organs* or parts differing from one another in their form, structure, and functions, but all nevertheless mutually dependent one upon the other, and concurring to a common end,—the preservation of the individual, which has place by virtue of an internal activity denominated *life*, amidst incessant changes and renovations of the matter entering into its composition, and the continuation of the species, which is a genesis or creation, implying neither destruction nor alteration in the mode of being of the individual or individuals from whom the new formation springs.

Actions of unorganized and of organized objects.— But form, size, material composition, duration, mode of origin, &c. are not the only particulars in the history of organic and inorganic bodies which are capable of being contrasted, and in which differences may be made to appear.

All that exists is *active;* every entity performs *actions*, or manifests forces by which its own existence is continued, and by which it participates in the various phenomena of the universe. Of these actions or forces there are two grand classes, the one *general*, the other *special:* the first are the physico-chemical laws which pervade space and include the universe; the second are the vital laws, which embrace within their dominion plants and animals, or things organized and having life.

The most general of all the forces possessed are those of attraction and repulsion, which inhere in, and are manifested by, all existing things, organic as well as inorganic. Every object gravitates or has weight, coheres in its several parts, exhibits chemical affinities, and yields to the expansive influence of caloric. Inorganic objects exhibit these general forces alone, and are absolutely under their control. Organized bodies are also subjected to the same general forces; but they are often modified, nay, they are sometimes even abrogated and set at nought by vegetables and animals alike, in virtue of the special powers inherent in themselves. These special powers have, in fact, the singular property of subtracting, in various degrees, the beings they actuate from the influence of the general laws of creation. Instead of obeying the universal law of gravitation, vegetables, for instance, shoot upwards, and propel their juices from the roots to the leaves; animals also distribute their blood in opposition to the laws of gravitation, and by their powers of motion overcome the universal physical law that tends to fix them in one place. The force of cohesion is not a merely passive property in the organized as it is in the unorganized world, and the laws of chemical affinity are especially set at nought both by plants and animals, their constituent elements being even generally united into combinations the contrary of those which these laws ordain. Animals and vegetables are farther abstracted from the general law of caloric, the more perfect of them at least having a specific temperature, independent of that of the medium which surrounds them, and which varies in conformity with changes in the peculiar actions of which in them it is the product.

There is even a distinction between the organized and unorganized world to this extent, —that while the physico-chemical laws dominate the inorganic world rigorously, and the bodies that belong to it seem to have begun to be as they continue to exist through, or in harmony with, their prescriptions, no organized body known has either sprung into being or continues to exist through the agency of purely physical or purely chemical forces. The whole of the special properties of organized beings consequently must be held to be effects of the agent denominated *life*, and of the laws which this agent originates. The organized world is, therefore, a creation within a creation, a something superadded to the material universe and to the generally pervading forces that keep its parts in their places, and endow them with what may be called their necessary properties.

Nor is it only whilst endowed with life that organized differ from unorganized beings. Many of the distinguishing and peculiar properties of these remain for a season at least after life has left the organization it had built up. The extensibility and elasticity of the tissues of animals especially, were held by the distinguished Bichat as even independent of life, which he owned increased their energy, but which he denied as their cause, seeing that they continue to exist after death. These properties are undoubtedly peculiar, and are at all events effects of forces which life has called into play, both the tissues which possess elasticity and contractility, and these qualities themselves having been engendered under the influence of vitality.

In these properties, forces or capacities of action common to all the objects of nature, unorganized as well as organized, we see the objection to the old denomination of *inert*, which was applied to one of the great classes. Nothing that exists is inert or inactive; but organized have an infinitely wider field of action than unorganized bodies. Let us, in illustration of this position, examine in succession the various actions by which bodies generally *originate*, *continue their existence*, undergo such *modifications* as they present in the course of their existence, and by which they *come to an end* or *die*.

Origin.—Unorganized bodies, minerals for example, commence their existence from the instant that circumstances exterior to themselves detach them from the mass of some other mineral, precipitate them from a state of solution in a fluid, or bring their constituent elements into a position in which they can combine together. In this, it is evident, there is nothing like *generation*, as the term is applied to organized bodies, which all alike, vegetables as well as animals, spring from a molecule, an atom, which has once belonged to, and which has proceeded from, a being similar to themselves. Vegetables spring from seeds, animals from eggs. Organized beings, therefore, are *engendered*, their existence is a consequence of that of other beings like themselves; and in their succession they depend one upon another. Minerals, on the contrary, have no powers of reproduction; they cease to be, if at any time they originate another mineral, and they are individually in a state of perfect independence.*

In the mode in which organic and inorganic bodies *continue their existence*, there is also a striking dissimilarity. In the inorganic world we observe no actions tending to preserve the individual, other than those which have presided over its formation: it continues to exist through the continuing agency of the affinities and of the attraction of cohesion which called it into being. Animals and vegetables, on the contrary, have special powers for their preservation superadded to those by the peculiar

* It were long to enter here into the discussion of what has been called *equivocal generation*, which, if admitted, militates against several of the inferences just deduced. It is quite certain that infusions of any organized substance do speedily become filled with animals distinct in their kinds and lately shown to be much more complicated in their structure than was long supposed. It is almost as difficult to conceive that these infusory animals proceed from eggs contained in the fluids in which they appear, as to imagine that they proceed from the combination, *per se*, of their constituent elements. Did we incline to admit the reality of equivocal generation, it is certain that its occurrence must be referred to other than the general laws of nature, with which we have already had occasion to show the laws of life to be in opposition, much rather than in harmony. It would be absurd to believe that these general physico-chemical laws, absolutely inimical to life, should at any time call it into being. Equivocal generation being acknowledged, therefore, it would seem necessary to infer a third order of laws besides the physico-chemical and the vital, the nature of which is altogether unknown to us. The number of creatures which were presumed to owe their being to equivocal generation, has been very much curtailed by the progress of science in modern times; and it is not impossible that the mystery which still overhangs the genesis of the infusoria may one day be dissipated, and their production demonstrated to be in harmony with those laws which are known to preside over the origin of higher classes of vegetables and animals.

agency of which they have been created. Inorganic bodies exist through the absence of all change in their interior; organized beings exist by force of change: there are two processes, one of renewal, the other of decomposition, perpetually going on within them; they are continually appropriating from bodies exterior to themselves a quantity of matter which they have the singular faculty of elaborating into their proper substance, and they have at the same time the power of withdrawing portions of the matter which already forms them, and rejecting these from their interior as no longer fitted for their preservation. Vegetables, by means of their roots and their leaves, draw from the earth and from the air materials which they elaborate into juices fitted for their nourishment, at the same time that they throw off, especially by means of their leaves, a portion of the matter which had been absorbed, either as superfluous or as improper to enter into their composition. In the same manner animals appropriate to themselves various amounts of matter in the shape of atmospheric air and food, from which they prepare a fluid proper for their maintenance, at the same time that they, by virtue of peculiar processes, withdraw from their bodies such portions of matter as have already fulfilled their destination, and cast them out under the form of excretions. Organized bodies, consequently, are preserved as individuals by a process of *nutrition*, a process which implies dependence on other bodies, and alternate appropriation and rejection of the particles of these; the existence of an organized being, in fact, only concurs with the presence and appropriation of substances external to itself, with a perpetual accession of matter on the one hand, and of its rejection on the other, whilst unorganized bodies are more certainly continued, as their state of isolation or abstraction from all external influences is more complete. Organized beings, in a word, continue to exist by virtue of certain inherent especial powers; unorganized simply by virtue of the general powers that pervade the universe in harmony with which they were originally framed.

The *modifications* undergone by organized and unorganized bodies are peculiar and characteristic in each class. In the first place modification or change is no necessary condition to the existence of an unorganized body, as it is of one that is organized. A mineral in a state of complete isolation might remain eternally unchanged; a plant or an animal, on the contrary, cannot be conceived as existing for a moment abstracted from the universe around it, and without undergoing change. A mineral, in the instant of its formation, acquires all the properties that distinguish it at any after-stage of its existence; in plants and animals, on the other hand, as we witness an origin, so we observe a series of modifications denominated *ages*,—they commence their existence, they increase in size, they attain maturity, and they decline and ultimately die.

Any change which unorganized bodies exhibit is accidental, and happens under the influence of agencies external to themselves; the changes which organized beings undergo in the course they run from incipience to their end, are on the contrary necessary, and take place in consequence of powers inherent in themselves.

Any change which an unorganized body experiences happens on its surface: its mass is increased or diminished by simple addition to or subtraction from its particles; it does not increase, neither does it shrink and decay in all its parts like plants and animals, in which increase and diminution take place at one and the same time from within and from without. Increase in the unorganized world happens through *juxta-position*, in the organic through *intus-susception*. Organized bodies, consequently, as they alone are *generated*, as they alone possess powers of *self-preservation* and of *reproduction*, so do they alone *grow*, advancing necessarily from *infancy* to *maturity* and *old age*, or exhibit what are called *ages*. (See AGE.) Organized bodies further meet our observation in two different states,—those, namely, of *health* and of *disease*, nothing corresponding to which is encountered in the inorganic world.

Whatever has a beginning has also an *end*. But the mode in which organized and unorganized bodies cease to be, and the influences that determine their periods of being, are extremely different. A mineral ends when the affinities that combined it, and the attraction of cohesion that held its particles together, are overcome. This language implies that its destruction is effected by agencies external to itself—by the action of other bodies, and of circumstances over which it has no controul. The destruction of a mineral is, therefore, in nowise *necessary*, neither is it *spontaneous*: abstract a mineral, as we have said, from all external agency, and its endurance is indefinite.

Very different is the case with regard to animals and vegetables; as their continuance depends on the process of nutrition, their end hangs upon the cessation of this act; and as the tenure by which they enjoy existence is temporary, the machine of organization being calculated to endure but for a season, their *death* or destruction is both *spontaneous* and *necessary*. Organized bodies which alone owe their being to *generation*, which alone *continue their existence*, *reproduce* their kinds, *grow*, *attain maturity*, and *become aged* by virtue of powers inherent within themselves, so do they alone *die*.

The period of endurance of unorganized bodies may often be calculated approximatively according to their masses, their densities, the aptitudes of their elements to enter into new combinations, &c.; that of organized bodies cannot be inferred from these or any other merely mechanical principles. Indeed, data from which the duration of organized bodies may be estimated are altogether wanting. We only know that every species has within narrow limits a period which it cannot pass; but why this period should, in particular instances, be confined to a few weeks, months, or years, or be extended to centuries, we cannot tell.

Nor is it only whilst endowed with all their peculiar and inherent properties that organized differ from unorganized bodies. No longer manifesting their especial powers, organized bodies begin to be disintegrated; their constituent elements, held together in opposition to the laws of chemical affinity, become amenable to these, and forthwith enter into new combinations, which imply the utter destruction of the organization as it had been formed, and hitherto preserved. Organized beings, as they alone *die*, so do they also alone undergo *putrefaction*— a process nothing precisely similar to which occurs in the inorganic world.

From this review of the distinguishing peculiarities of organized and unorganized bodies, it appears that organization implies vitality, and that organization and life are inseparable conditions. It would be going too far to say that they were synonymous terms: *organization* is the mode of structure proper to living beings; *life* is the series of actions they exhibit. And this in fact appears to be about the least objectionable definition of life than can be given: *life is the series of actions manifested by organized beings;* would we go farther, we must condescend upon an enumeration of these actions,—namely, incipience by a *genesis* or creation; temporary endurance as individual by *nutrition*, and indefinite continuance as species by *reproduction*, modification during the term of existence known by the title of *age*, and end by *death*, to which specific acts or phenomena must be added the peculiar inherent power which living beings possess of overcoming the general physico-chemical laws that dominate the rest of the universe.

Thus far we have discussed and contrasted the physical qualities and phenomena common to organized or living beings at large, with such as inhere or are manifested by unorganized bodies generally, more especially minerals; we have still left untouched those that severally pertain to the two grand divisions of the organized world, and that are peculiar to each living thing individually; and here we shall find that the manifestations of vitality are almost as various as the species that people the earth. In the same manner as we have hitherto gone on contrasting first the material composition, and then the actions of organic and inorganic bodies, we shall still proceed by comparing the material composition and the capacities of action of the different classes of organized beings first, and next of the several individuals composing these classes one with another.

Comparison of animals and vegetables.

Animals and vegetables were longheld essentially and irreconcilably distinct from one another. We have already had occasion, however, to observe in how many particulars they are identical. The material composition of both is often in opposition with the general physico-chemical laws, both are made up of a combination of solids and fluids, both consist of a variety of heterogeneous parts, and both have determinate sizes which they cannot exceed. Moreover, both are possessed of vitality,—in other words, both commence by a genesis, preserve themselves as individuals by nutrition, and as species by reproduction; both grow by intus-susception, undergo the mutations which are denominated ages, endure for a time, present themselves in health or labouring under disease, and both decay and die. How intimately animals and vegetables are associated, how nearly they resemble one another, will farther appear as we advance in the following

Comparison of the general physical qualities and material composition of Vegetables and Animals.—As a general axiom the material constitution of vegetables may be said to be less complex than that of animals; this at least is more especially the case as the individuals at the top of the two scales are concerned.

No distinguishing feature of either class is derivable from general diversity of *Size*. Between the microscopic lichen and infusory animal, and the gigantic adansonia and whale, plants and animals of every intermediate magnitude are encountered.

Neither is there much to be said upon the differences which vegetables and animals present when their *Forms* are contrasted. The forms of many are alike amorphous, or simply globular; certain pulverulent fungi in the one class, and monads in the other, resemble each other greatly. Among both, individuals also occur whose parts are disposed around a centre; yet we do not advance far before we discover a peculiarity in animals, namely, composition by the union of two similar or symmetrical halves along a middle line or axis, nothing similar to which has even been imagined in the vegetable world, the members of which on the contrary often exhibit a horizontal division, but without anything of symmetry, into root and branches. As a general law the animal kingdom may be said to affect the globular or simply produced form, with radii in the shape of extremities sent off from a central part; the vegetable to exhibit a greater tendency to ramification or division into branches.

In point of *chemical composition* animals and vegetables consist very nearly of the same elements: oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, iodine, bromine, chlorine, potassium, sodium, calcium, silicium, magnesium, manganese, and iron have been detected in both; aluminium and copper have hitherto only been discovered in vegetables, and fluor only in animals. But these elements are united in each in very different relative proportions. Carbon predominates greatly in the more solid parts of vegetables, nitrogen in the bodies of animals generally, although to this rule there are many notable exceptions; albumen, fibrine, and gelatine all contain much more carbon than nitrogen, and certain fungi include a very large proportion of nitrogen in their composition. Several elements, met with abundantly in animals, occur but sparingly distributed among vegetables, phosphorus, for example, and sulphur. The earth afforded by animal bodies incinerated, is mostly lime in a state of saline combination; whilst that yielded by vegetables, besides lime, consists of alumina, with an admixture, greater or smaller in amount, of scilica.

The peculiar combinations which form what are called *immediate principles*, are much more numerous in the vegetable than in the animal kingdom, and are also generally more simple in the former than in the latter, the immediate principles of vegetables being mostly ternary compounds, whilst those of animals are generally quaternary, nitrogen being added in these last to the carbon, hydrogen, and oxygen, which form the organic elements of the first. The immediate principles in both classes are divided into acids and oxides; and many of these they have in common. Vegetables, however, have a third order of substances entering into their composition, of which we discover no traces among animals; these are the vegetable salifiable bases.

There are but few *acids* which exist in the vegetable and animal kingdoms in common; and whilst their number is small among animals, it is very great among vegetables.

The hydrocyanic acid has only been discovered in vegetables; when it is procured from animal substances, it is always formed under peculiar circumstances, or during their decomposition.

Of the organic *oxides*, some—albumen, osmazome, sugar—are common to both animals and vegetables; but they occur in very different proportions in each: sugar, which is so abundant among plants, is scarcely to be detected among animals; and osmazome, which is so universally distributed among animals, has only hitherto been discovered in a few fungi. Of the ternary compounds of carbon, hydrogen, and oxygen, such as *starch, gum, sugar, the resins, woody fibre, fixed oils, volatile oils, camphor, extractive matter, &c.* which enter so largely into the constitution of vegetables, there are but a very few to be discovered among animals, such as the sugar of the milk and urine, the resin of the bile and of the urine, the elaine and stearine of the fat, the volatile oily principle of castoreum, &c. and the camphor of cantharides.

The quaternary organic compounds of carbon, hydrogen, oxygen, and nitrogen, which form the principal elements in the composition of the bodies of animals, are, on the contrary, very rare among vegetables. The most common of these are albumen, gelatine, fibrine, animal mucus, and osmazome; the less common enumerated are the matter of the saliva, caseous matter, urea, and the pigmentary matter of the eye.

Still vegetables are not without several of these quaternary compounds, such as albumen and osmazome, and they even possess others which are peculiar to themselves, such as gluten, the matter of the pollen of flowers, indigo and several extractive colouring principles; to say nothing of the whole exclusive class of salifiable bases, quinia, cinchonia, veratria, strychnia, morphia, &c., &c., which appear to be compounds of carbon, united in large proportion with a little oxygen, hydrogen, and nitrogen.

Comparison of the organic composition or texture of animals and vegetables.—We find many and much more striking differences in the texture than in the chemical composition of the two great classes of organized beings. Both are made up of solids and fluids; but with a few exceptions, the proportion which the solid bear to the fluid parts is much greater in vegetables than in animals.

The fluids contained in the bodies of the higher animals, the blood, chyle, spermatic fluid, bile, urine, &c. have in general a very different character from those that constitute the sap of the more perfect vegetables, or that are deposited as secretions in the nectaries and various cavities of their flowers, leaf-stalks, stem, &c.

But the solids, entering into the composition of each class, are still more widely dissimilar both in their outward and in their intimate characters. The most simple vegetables, the cryptogamia, appear to consist of a homogeneous tissue, forming rounded or oblong cells filled with fluids or a granular substance, without any trace of proper tissue; it is only when we come to the phanogamous vegetables that we find any distinction of tissues, namely, a cellular and a tubular tissue, the whole body of the plant being surrounded with a distinct integument or bark.

The *cellular* tissue of vegetables, whilst still young, is soft, homogeneous, and contains cellules filled with a fluid often charged with globules; when full grown, this tissue is made up of cells properly so called, being spaces surrounded with solid membranous parietes of various forms and sizes containing different matters. These cells appear composed of vesicles placed side by side and running one into another, surrounding the spiral and nutrient vessels of the stem and bark, and opening so as to form reservoirs filled with air, or resinous, oily, or mucilaginous fluids.

The *tubular* or vascular tissue of vegetables occurs under two different forms—spiral vessels, and nutrient vessels. The former present themselves in great abundance amidst the woody fibres, but penetrate also into the leaves, and even into the stamina, pistilla, and fruit. They are not met with in the bark. These vessels seem specially destined to include and conduct the sap, which from the root ascends to the extreme branches and leaves of all vegetables. The nutrient vessels, so called from containing a fluid, the cambium or succus proprius, different from the sap, prepared from this by elaboration in the leaves, have now been demonstrated in a great number of vegetables; they are principally contained in the soft inner layer of the bark, but they also penetrate every part for the purpose of conveying the essentially nutritive juice or blood of the plant.

These elementary tissues, combined and arranged in a great variety of modes, constitute the root, trunk, leaves, flowers, and fruit of all vascular vegetables; and it is wonderful how nearly the whole of this tribe, however dissimilar in their outward appearance, resemble one another in their intimate structure.

The tissues that enter into the composition of animals are much more numerous than those of vegetables. The most universally distributed of these in the more perfect species of animals are the cellular, the vascular, the nervous, and the muscular, to which must be added the tendinous or fibrous, the osseous, the cartilaginous, and the horny, which are less uniformly diffused among the individuals composing the animal kingdom.

The *cellular* is the tissue the most universally encountered among animals; it is demonstrable from the very lowest to the very highest. Its general appearance is that of a soft, homogeneous, whitish, semi-transparent, extensible, and during life slightly contractile substance. It is permeable to air and liquids, and is easily distended by either of these, when it forms a series of continuous cavities or cells, strangers at first to its constitution, but so readily produced as to have given the tissue its distinguishing title. The cellular tissue is dispersed abundantly through every part of the animal body; it enters as a principal element into the composition of many other tissues; it pervades the innermost parts of almost all organs, and in a modified shape forms a covering for them externally; it may be said to constitute the frame-work of the organs generally, supporting them in their particles as it does in their masses; it connects them together also, includes and accompanies the bloodvessels that supply them with nourishment, fills the intervals between them, and establishes continuity between every part of individual organized beings. The cellular tissue consists of filaments and laminæ, mingled and entangled together; the interstices it contains, and which may be blown up into cells, appear to be moistened during life by a thin vapour, or a variable quantity of serous fluid.*

The cellular substance appears to constitute the element of the various *membranes* encountered in animal bodies: the fibrous membranes, the skin, the mucous membranes, the serous membranes, and the synovial membranes, are all readily resolvable into cellular tissue; they in fact appear to consist of this tissue in different states of condensation.

The *vascular* is another tissue extensively distributed among animals. Three modifications of the vascular tissue have been reckoned by anatomists, occurring respectively in arteries, veins, and lymphatics.

The third tissue which is peculiar to animals is the *nervous*. This may be held the most eminently distinctive of this class of organized beings, as it is by its intermedium that they exhibit almost all the faculties which place them so immeasurably above vegetables in the scale of creation, and as, generally speaking, they may be reckoned by so much the more perfect as particular portions of this system are more fully developed. The element of the nervous tissue is a soft, whitish, and little consistent substance, composed of minute globules surrounded by a semifluid substance, and connected together by a tissue of cellular membrane of extreme tenuity. The globules are mostly disposed longitudinally, when they form the medullary fibres of the brain; surrounded by denser sheaths, they take the form of nerves. In all the higher animals at least, two orders of nerves are distinguished, each, however, being intimately connected with the other,—the nerves of *animal*, or, better, of *phrenic* life, and the nerves of *organic* or *vegetative* life. The nerves of the first order are connected in the higher classes of animals with a brain and spinal cord; those of the second proceed from small bodies of a reddish grey colour, and irregular shape, named ganglions. The functions of the first take place with consciousness, those of the second without this mental phenomenon.*

The fourth tissue peculiar to animals is the *muscular*. In several of the very lowest tribes of these, indeed, the existence of this tissue cannot be demonstrated; yet its actions begin to be manifested at a very low grade in the scale. The element of the muscular tissue is a fibre, on the ultimate constitution of which there have been many disputes. The ultimate muscular fibre would appear to consist of a series of solid globules longitudinally disposed, and connected into larger and larger fasciculi, which at length compose the distinct bundles denominated muscles. Fibrine is the organic element of the muscular tissue. Its peculiar and distinguishing property is its capacity to contract or to become shorter, and to relax again or return in its quiescent state to its first lentgh.

The muscles, like the nerves, are divided into two classes or orders, the one under the influence of the will, the other independent of it. The texture is different in each of these two orders: in the voluntary muscles, the fibres and bundles of which the peculiar tissue consists are very regularly disposed, and generally in straight and parallel lines relatively to one another; in the involuntary muscles again, the fibres appear of different degrees of density, run parallel or obliquely with regard to one another, are superposed in layers, intermingled and entangled like a kind of felt, &c.

* Rudolphi assigns as a distinction between animal cellular tissue and that of vegetables, that the latter exhibits cells of a more or less regular form with firm walls, nothing of which kind exists in the former: Rudolphi Anat. der Pflanzen, S. 26, quoted in Tiedemann, Physiologie, 1ster Band, S. 182.

* Some physiologists have gone so far as to suppose a rudimentary nervous system among vegetables, which would imply consciousness on their parts of their existence. This, at least, is a very doubtful presumption, but we are not without abstract arguments which might be adduced in favour of the supposition. How immensely would the sphere in which the bounty of the Creator had displayed itself then appear enlarged! The number of beings conscious of the joys of existence would be increased a thousand fold; and it is even delightful to imagine these lower partakers of organization with ourselves and animals, also enjoying the light and sunshine, the sequence of day and night, the freshness of spring, and the fulness of autumn.

The fifth tissue which prevails among animals is the *fibrous*. This is or may be divided into the *tendinous* and *ligamentous*. These are alike subservient to the muscular tissue and to the function of voluntary motion. They consist of fibrous, parallel bundles, of a white colour and pearly lustre, of great strength, and possessing little elasticity.

The sixth tissue which is peculiar to animals (the first of those less universally distributed) is the *osseous*. This forms the frame-work or skeleton which gives form and fixity to all the other parts entering into the constitution of the higher animals. The essential organic element of bone is a cellular net-work consisting of gelatine, within the meshes of which certain calcareous salts, the phosphate and a little carbonate of lime especially, are deposited in order to give them greater solidity.

The *cartilaginous* is generally reckoned as the seventh among the elementary tissues of animals; it may and has been very properly assimilated to the osseous: the bones are cartilaginous at first, and with the progress of years many of the cartilages show a tendency to, or do actually become, converted into bone. The cartilages that cover the articular heads of the bones are almost the only ones that show no disposition to undergo this change. The organic element of cartilage is gelatine.

The *fibro-cartilaginous* is a mere modification, although an interesting one, of the cartilaginous or rather of the fibrous tissue. The fibro-cartilages are very strong, and particularly elastic.

The horny and calcareous coverings of insects, and the crustacea have uses corresponding to those of the bones. The calcareous shells of the mollusca, too, bear a certain, though a very remote analogy to the skeletons of the higher animals.

The *horny* or eighth tissue peculiar to animals might with propriety be reckoned among the number of those that are very widely distributed. We meet with it in the epidermis of man, and as low in the scale at least as the molluscs and annelides; it is the most universal clothing provided by nature for the bodies of animals.

So much for the simple tissues entering into the composition of animals, to many of which nothing analogous can be discovered among vegetables. But these are by no means the only solid elements that make up the aggregate of animal bodies. The *organs*, as we entitle them, for the performance of certain functions so generally encountered among animals,—the lungs, liver, stomach, kidneys, testes, ovaries, &c., &c., are so many peculiar compounds of the more simple tissues, occasionally with additions denominated *parenchyma*, nothing corresponding to which has ever been discovered among vegetables. These various organs are associated in animals into groups, denominated *systems*, which severally tend to the accomplishment of the individual functions manifested by the creature examined,—the teeth, tongue, salivary glands, œsophagus, stomach, liver, pancreas, and intestinal canal, constitute one great and important system, subservient to the conversion of food into nourishment, and the preservation of the individual; the testes, penis, vagina, uterus, and ovaries, in the two sexes, compose another great system by which the species is continued, and so on.

Besides these solids we have a great variety of *fluids*, which in animal bodies subserve various and important purposes: we have, for instance, the general nutrient fluid distributed to all parts of their bodies, denominated *blood*. We have a variety of fluids prepared for aiding or accomplishing the act of digestion,—the *saliva*, *gastric juice*, *pancreatic juice*, and *bile*; we have various fluids as emunctories of the worn-out parts and particles of the system,—the *perspiration* and the *urine*; and we have a peculiar fluid prepared as a means of continuing the species—the *spermatic* fluid. Fluids corresponding in their destination to one or two of these are also met with among vegetables, but there they are greatly modified.

Comparison of the vital manifestations, or actions of vegetables and animals.—In considering generally the manifestations of vitality in vegetables and animals, we immediately become aware of very distinct and peculiar tendencies in each class. A disposition to produce diversity of parts, and a symmetrical arrangement of these, are as striking features in the acts by which animals are evolved, as the opposite or a disposition to reproduce to infinity similar parts without symmetry is a character inherent in vegetables. The liver, spleen, heart, intestinal canal, pancreas, and vertebral column, are the principal asymmetrical parts in animals; the organs of the senses, the lungs, kidneys, testes, ovaries, lateral bones of the head, and extremities, and the muscles, are the principal symmetrical parts; and these severally cannot be said to be repeated,—they only exist in pairs, on either side of the mesial plane. Such accessory and unessential organs as hair, scales, feathers, &c. are the only ones that are found repeated among animals. The very opposite of this tendency prevails among vegetables; we find nothing like symmetrical arrangement on either side of a middle plane, and we see the same parts repeated again and again to infinity, so that any single part, a branch, for instance, becomes an epitome of the entire tree.

Another peculiarity in the mode in which the vital processes build up vegetables and animals consists in the situation and disposition assigned to the various organs entering into their composition. Whilst in plants the whole of the organs destined to the manifestation of particular functions,—the leaves, flowers, stamina, pistilla, roots, &c.,—are placed externally, and their interior or trunk is a mere prop upon which these parts are hung, in animals the whole of the essential organs destined for the preservation of the individual and continuation of the species are concealed, so that their exterior is the shell, their interior the receptacle for the especial lodgement and protection of these.

Such diversity in the arrangement of the parts composing vegetables and animals does away with the necessity for the existence among the former of any thing like those *central organs* found in the latter, which, from the interior of the body, and generally from the mesial plane, send off radii of communication to every atom of the organization, and prove the media that unite their several and often widely separated parts into a whole. We discover nothing like prolongations from central organs—from a heart, an artery, a stomach, and a spinal cord or ganglionic system, among vegetables. Hence the independence of the several parts of vegetables one upon another, hence their susceptibility of being multiplied by cuttings, and even of some species arising complete from their leaves.

A third and very important peculiarity in regard to the mode in which the vital processes are performed in the animal and vegetable kingdom is that many take place with *consciousness* or knowledge of their occurrence, in the one, whilst they all occur *unconsciously* in the other. In vegetables the whole of the acts whose sum constitutes their vitality are perfectly irresistible, and take place in them without their knowledge, and uninfluenced by their will. A great many of the vital acts, indeed, take place without consciousness among animals also, such as the circulation of the blood, the digestion and assimilation of the food, &c., but the moment the animal passes the sphere of its individual existence, whenever it has to act beyond itself, we find consciousness of the action superadded to the capacity to act. The very lowest animals *select* their food, search for and appropriate their aliment as it presents itself to them; the most perfect vegetable, on the contrary, absorbs irresistibly, and without perception or will, the materials brought into contact with its roots in the earth, and its leaves in the air. The same wide differences are apparent in the act by which the species is continued: animals search for, and, by an inherent virtue denominated *instinct*, implying consciousness, distinguish the other individual of opposite sex, of which they have need in order to procreate their kind; in vegetables, on the contrary, all is passive; the pollen or fecundating powder is projected or falls upon the pistillum, or is even left to be brought into contact with this part by accident, without participation in the act, without consciousness of or will in its performance.

These two last named manifestations, the one subservient to the preservation of the individual, the other to the continuance of the species, are accompanied with such circumstances in animals as presuppose in them other two peculiar faculties: these are *perception* and the *power of locomotion*. To preserve themselves as individuals and as species, they required powers which should make them acquainted with and enable them to establish relations between their own bodies and the world beyond them. By the faculty of *perception*, which may be taken as synonymous with *sensibility* in its widest acceptation, an animal is made aware of his individual existence, as well as of that of the material universe without him. This faculty also takes cognizance of all the internal sentiments, feelings, or desires of which by his constitution he is susceptible, and which are always in harmony with the part he is destined to play in creation. Sensibility may therefore be defined: the faculty by which impressions from without as well as sensations, emotions, and intellectual acts from within are perceived. The organ of this faculty is by universal consent admitted to be the nervous system. The faculty itself, as the above definition indicates, is susceptible of being considered under two heads: as the impressions perceived or perceptions come from without, or as they emanate from within. The organs of the senses are the media through which external impressions reach the percipient principle which resides in the brain and medulla oblongata in the higher animals, the nervous ganglia in the lower, and these same parts are the instruments or elaboratories of the internal sensations. Both of these kinds or modes of perception were alike necessary to the beings endowed with them. The external sensations are the watchmen of the system, admonishing animals of the presence of the objects they require for their preservation; the internal feelings, in like manner, are centinels which admonish them of their wants and lead to the employment of the organs by which these may be supplied.

By the faculty of *locomotion*, again, an animal accomplishes all the promptings of his inward nature; he places himself in relation with the beings and the things which he is admonished by his instincts or internal faculties are necessary to him for his preservation as individual and continuance as species. Made aware of his wants by perception, by the faculty of locomotion he is enabled to minister to them. These two powers, let us observe, always exist together; the one, indeed, necessarily supposes the other. Sensibility or perception is the monitor, locomotion the agent. Without perception locomotion could have subserved no end; without some capacity of locomotion perception would have been a vain inheritance.

Vegetables evidently possess no power of locomotion analogous to that inherent among the higher animals,—where the seed falls there the plant springs, there it attains maturity, and there it dies. Neither do they manifest any thing like sensibility in outward act that can be ascribed to volition or consciousness: their nature, in fact, made perception unnecessary to them; and having no power of locomotion, it would have been useless in the two great acts by which organized beings minister to their preservation as individuals and to their existence as species. Still it is impossible to deny every thing like capacity of outward motion to vegetables. Although they have no power of transporting themselves over the surface of the earth or through its waters like animals, many of them exhibit motions in their leaves and flowers in relation with the state of the atmosphere, and the diurnal revolution of the earth; the sexual organs in several species move the one towards the other; and about the foot-stalks and petioles of the mimosa *pudica* and other plants we observe particular organs that contract when stimulated, very much in the same way as the muscular fibre among the higher animals. Moreover, the motions by which the radicle constantly seeks the ground or tends downwards and the plumula shoots into the air, that by which some of the higher phanogamous plants twist in spirals around objects near them, and by which all preserve one side of their leaves towards the light, cannot be held as accidental or merely mechanical acts. Several genera of the confervæ and tremellæ even exhibit such remarkable oscillatory movements as have induced different naturalists and physiologists to reckon them among the number of the animals.

With all this, however, locomotion among vegetables is a very limited power contrasted with the faculty among animals. These exhibit all the automatical motions of vegetables, and have in addition a particular system, the muscular, superadded to their organization, by which many of the most important offices of the economy are performed: not only instrumental in procuring the food by which they are maintained, but in putting into play the digestive and respiratory apparatus by which the nutritive juices are prepared and assimilated, and finally distributed among the higher tribes to every part of the body. The existence of this system is in fact one of the grand characteristics of the more perfect animals. By its means they react upon the external world and modify it according to their wants; by its means they guide their senses and enlarge the sphere of their acquaintance with things beyond themselves; by its means they impress the air with the tones and articulate sounds, or execute the signs by which they make known the various states of their affective or moral and intellectual being to one another; finally, by its means the sexes approximate, and those acts take place which lead to the engenderment of new individuals and the continuance of species.

The best informed among physiologists, however, do not confine the motions of all animals to the act of the particular tissue we denominate muscular. The polypes and many even of the massy acalephs, to say nothing of the smaller infusories, rotifers, &c. though they move freely, cannot be shown to possess muscular fibres in their constitution; neither indeed can any nervous system, upon which muscular contractions and voluntary motion have always been held dependent, be demonstrated in these creatures. It is consequently probable that the means by which spontaneous motion takes place in these lower animals are peculiar, as indeed we must acknowledge the evident motions which occur under many other circumstances in the world of organization to be.

But let us now turn to the *special* manifestations of vitality of the two great classes of organized beings we are engaged in examining. These we shall consider in the following order, which is also that we have adopted in contrasting the manifestations of activity of unorganized and organized beings,—namely, *origin* or *reproduction*, *nutrition* or self-preservation, *changes* undergone during the period of existence, or the *ages*, and *death*, or end.

Origin, *or the acts by which species are continued.*—Vegetables and animals alike derive their origin from a birth or genesis accomplished in two different modes, either without the concurrence of opposite sexes, or with such a concurrence. When organized beings are produced without the concurrence of opposite sexes, the parent either divides into several pieces, each of which becomes an independent individual, or throws out burgeons or buds from its surface, which, being detached in due season exist as self-sufficing types of the species. When organized beings spring from the concurrence of sexes, again, two sets of organs minister to the generation, the one denominated *male*, supplying a fecundating matter, the other entitled *female*, furnishing a germ, which subsequently to its impregnation by the male organ undergoes a series of evolutions that end in the issue of an individual resembling the parents, and fitted by its own acts to preserve itself and to continue its kind.

Both of these modes of reproduction are common to vegetables and animals. Confervæ and polypi alike exhibit the first mode, almost without a difference: buds or sprouts arise from the surface of both; these adhere for a time, acquire a certain size, and are finally detached to become independent beings. Again, the polype divided into several pieces, gives origin in each of these parts to distinct polypi, exactly as the cuttings of vegetables take root and grow into perfect trees, shrubs, &c.

The second mode of reproduction—that by the concurrence of sexes, or of organs denominated respectively *male* and *female*,—is also exhibited by vegetables and animals indifferently; but there are numerous circumstances distinguishing this manner of reproduction in the two classes of organized beings. In the first place, the sexual organs do not exist from the earliest period, and during the whole course of the life of vegetables, as they do in animals; the sexual organs, in fact, only occur among vegetables at the time of flowering, and perish whenever the end of their evolution has been accomplished, never serving oftener than once for the generative act. The sexual organs of all animals, again, that live for more than a year, suffice repeatedly for their office; and if they are not required to accomplish this oftener than once in the short-lived tribes, it is probably from no inherent incapacity to serve again, or any destruction of the organs themselves, but simply because the term of existence of the organism of which they formed a part is complete,—they perish with the system to which they belonged.

Another grand though not an invariable distinction between vegetables and animals is the mode in which the sexes, or sexual organs—for these may be taken as synonymous terms—are distributed among the individuals of each class. Speaking generally, it may be said that the sexual organs are as commonly divided between *two* individuals among animals by whom the species is represented, as they are confided to *one* among vegetables, which is, therefore, singly the type of its kind. In both classes, indeed, there are exceptions to this general law: the flowers of all vegetables do not contain stamina and pistilla, or male and female organs, neither are the opposite sexes invariably represented by two different individuals among animals. In many plants the male organs are known to exist in one flower, the female in another, but both developed on the same branch; in many others, again, they exist on different stems, and are often evolved widely apart from one another. In the same manner, many of the lower tribes of animals include within their individual organisms male and female organs; this is the case with several tribes of the genus mollusca, gasteropoda, the helix, limax, and lepas, for instance, with the whole of the extensive classes of the annelida, entozoa, echinodermata, &c.

But though there be resemblance to this extent among vegetables and animals in regard to organs, in the act by which fecundation is accomplished there is a wide and essential difference; for whilst vegetables impregnate themselves, or, rather, whilst the impregnation of vegetables is a purely passive process, without perception of or concurrence in its accomplishment on their parts,—the pollen of the anthers of those flowers that have male and female organs being simply shed upon the pistilla, the impregnation of animals, so far as our knowledge goes, appears to be almost as generally a consequence of a connexion between two different individuals, and of volition with consciousness on their several parts. Although many animals have both male and female parts included within the same organism, it would seem that comparatively few have the power of impregnating themselves: two individuals of the like species meet, and *give* and *take* reciprocally; so that there is, in fact, much less difference between the highest and the lowest tribes of the animal kingdom in the essentials by which races are continued, than at first sight appears, much less certainly than there is between the vegetables and animals that are most nearly allied. The modes in which fecundation takes place in vegetables at large, and in animals probably without exception, are inherently and essentially distinct: an hermaphrodite animal is still a very different thing from an hermaphrodite flower.

Another difference between vegetables and animals, less important, indeed, but still interesting, lies in the *number* of the organs possessed by each destined for the continuation of the species. In many vegetables the organs are *single*, one flower being taken as a representative of the sexes; in a much larger proportion of plants, however, the organs are *multitudinous*. Among animals, on the contrary, with a few exceptions in the very lowest tribes, the asterias, &c. where they are multidinous, the essential male and female organs, the testes and ovaria, exist singly or in pairs only.

A third diversity, and one that is striking and almost universal, between those species of plants and animals in which the sexes are represented by two individuals, lies in the difference of conformation, size, and general character of the individuals in the one class, and their perfect similarity in the other. There are very few diœcious plants the males of which are distinguishable from the females; there are very few tribes of animals, on the contrary, in which the distinction of sex is not extremely apparent, the males being generally larger, stronger, and more courageous; the females smaller, more delicately formed, and more timid in their disposition.*

A fourth distinction which deserves to be noted betwixt animals and vegetables is in the diversity of the act by which the new being is separated from the parent, and commences its independent existence. The period at which this happens, indeed, is determinate, and fixed in both alike, but it is accompanied with consciousness among animals, whilst it is altogether unwittingly accomplished among vegetables.

From this review of the mode in which animals and vegetables are called into being, or of the acts which lead to their creation, the main and most striking differences observable in the two classes are these: whilst in vegetables the whole of the acts that constitute reproduction,—the union of the sexes, the fecundation of the ovum, and the birth of the new being are accomplished without the will and without the consciousness of the individual, but irresistibly and necessarily, they are left in some particulars, at least, to the will, and take place with the consciousness of the individuals among animals.

Nutrition, *or the acts by which the individual is preserved.*—Every thing in nature changes, and organized beings only continue their existence with their aptitudes to manifest the acts that draw so wide a line of demarcation between them and unorganized bodies, by a perpetual renewal or recomposition, and as incessant a rejection or decomposition of their elements. Nutrition is, therefore, at least, a two-fold act, implying *absorption* or *appropriation* of nutritive matter, and *excretion* or *rejection* of the old and worn-out particles that have already served their office in the economy: it consists, in fact, as we have said, of an incessant decomposition and reconstruction of the fabric of the living organized being. Nutrition, however, is a very comprehensive term, and includes the whole of the vital acts by which the individual continues

* One of the most striking exceptions to this law occurs among some especially of the smaller species of the birds of prey. In many of these the female is much more powerful, heavier, and even more courageous than the male. The care of the offspring, by one of nature's ordinances, devolving principally upon the female, the supply of flesh for the brood—a supply procured by violence—might often have failed had she not in these tribes been provided with superior strength and courage to insure its regularity and abundance.

its existence,—namely, among the higher tribes of living things, the absorption or ingestion of food or alimentary matter; the preparation of this food by the processes of digestion and respiration; the distribution of the nutritive matter fitted for its ends, to every part of the system by means of a circulation; the conversion of the nutritive matter into the solids and fluids or proper substance of the individual, and finally the depuration and rejection of the worn-out parts and particles by means of certain secreting organs. These various processes in themselves will be particularly considered in the article Nutrition, to which the reader is referred. Meantime let us contrast these different functions as they manifest themselves in each of the two grand divisions of the organized world.

Assumption of aliment. — The earth and the atmosphere, and the carbonic acid and water they contain, are the sources whence vegetables derive their food. Here they find aliment ready prepared for their use, or rather, as passive agents, they depend on the earth and the atmosphere for a supply of the elements required for their continuance. Those physiologists are now admitted to have been mistaken who supposed that the food of vegetables was furnished by the inorganic earth, air, and water, with which their roots and leaves are in relation; more accurate experiments have shown that plants are as dependent as animals on supplies of substances that have once had life for their support. When plants are made to grow in pure earth and in distilled water, they appear to do so by a kind of decomposition of themselves, one part perishing and affording food to that which continues to live. To base a distinction between animals and vegetables, consequently, on the presumption that the one lived on organic, the other on inorganic substances, was incorrect: animals and vegetables are alike in this respect; both feed upon organized matter, and this not always or necessarily in a state of decomposition, as we observe among parasitic tribes, which subsist on the living juices of the individuals they cling to. The food of animals, however, may be stated generally to be both more various and also more complex in its chemical composition than that of vegetables, and whilst vegetables take all their food in a liquid shape, animals much more commonly live on a mixture of solids and fluids.

The assumption of food by vegetables and animals takes place under very different circumstances. In vegetables it is necessary and independent of the individual; it is also incessant; and, farther, it takes place from the external surface, inasmuch as it is with this that the materials which supply the nutriment are in contact.

Animals, however, have not generally their food prepared for their use brought into contact with their bodies, neither are they passive in its assumption; they have mostly to search for it abroad, and are provided with special organs for this purpose. The act by which they take it is not necessary, neither is it incessant. They have also to select their food, and are, therefore, furnished with faculties which guide them in their choice; namely, taste and smell. Lastly, the absorption of the truly nutritious matter is accomplished from their interior, the crude material assumed as food having been first prepared by elaboration in a cavity called a stomach.

As organized living beings, the soundest philosophy and best ordered experiments lead us to infer that there is little if anything *mechanical* in the mode in which either vegetables or animals absorb nutriment. The absorption of their aliment by vegetables is influenced by the seasons, their state of health or disease, their age, and external circumstances generally,—the temperature, state of dryness or moisture, &c. of the air with which they are surrounded; the cause of the absorption of their food by vegetables is, therefore, something different from what is called capillary attraction, or the law by which fluids ascend in tubes of small calibre.

The proper passage of the nutriment into the bodies of animals occurs from their interiors, and in a very large proportion (probably in every somewhat perfect member) of the class, by means of a special set of vessels denominated lacteals or lymphatics, no system corresponding to which exists among vegetables.

The very lowest tribes of the animal kingdom, the entozoa, acalephæ, polypi, &c. having no proper vessels of any kind, the cellular membrane of which they consist absorbs, and by virtue of a peculiar vital process, distributes the nutritive juices extracted from the matters received into the stomach and alimentary canal to all parts of their bodies. Those tribes of animals which have naked skins have the faculty of absorbing by their exterior also.

Still less than in vegetables, can we suppose that the process by which in animals nutriment is ultimately absorbed into the body, whether from the exterior or the interior, is akin to mechanical or capillary attraction. The tissues of which animal bodies consist are, indeed, permeable to fluids, but this does not explain the collection of these fluids in so many tribes into particular canals, and still less does it solve the problem of the continued motion onwards in determinate directions within these channels.

Absorption of alimentary and other matters, therefore, in both of the grand divisions of the organized world, must be held as a vital act,—as one of the particular laws superadded in organized beings to the general system of physico-chemical ordinances that rule the universe and its parts. This quality is common to vegetables and animals.

By far the greater number of animals have one or more special openings,—a mouth or mouths, by which they take in such substances as are fitted for their nourishment. Even the greater number of animals as low in the scale as the infusoria, have been recently demonstrated (by Ehrenberg) to be provided with an opening of this kind. Several, however, seem to receive aliment by the way of absorption alone. The mouth is a cavity of extremely varied character and construction adapted universally to the circumstances in which animals exist. Nothing analogous to a mouth is met with in any vegetable.

The food having been selected and seized is next transferred to the cavity in which it undergoes an elaboration that fits it to be received into the proper system of the animal and converted into its own substance. We do not find anything like the pouch denominated a stomach in any member of the vegetable kingdom. The matter fitted for its nourishment, absorbed by the root, is transmitted to the stem, and from thence makes its way into the leaves of the vegetable. It does not pass unchanged, however, from the earth into the root, or at least it has advanced but a very short way on its course to the leaves, before it is found to have undergone certain changes, which are also known to be greater in amount as it is examined at a greater height or distance from the root. Although growing from the same soil too, the sap of vegetables, i. e. the fluid which is passing upwards through the woody fibres, is found to be universally different. Whether the peculiar qualities thus acquired by the simple moisture holding certain salts, &c. in solution, which is the food all vegetables derive through their roots, be the effect of vital elaboration within the cells of the woody fibre, or result from an admixture of the cambium or fluid which has already undergone assimilation in the leaves, is still uncertain. We are inclined to believe that a process analogous to digestion does actually take place within the woody conduits of the sap of vegetables;—why should it not, or why should any new properties acquired by matters subjected to the influence of the peculiar laws of vitality be held as resulting from mere admixture?

The very same thing, in fact, happens among the lowest tribes of animals which takes place in all vegetables: the substances fitted for their nourishment penetrate or are absorbed into their systems, and are there assimilated without the intermedium of any special apparatus. We mount but a very short way in the scale of the animal creation, however, before we meet with a peculiar pouch, destined for the reception of the aliment, and accomplishment of the first steps in the processes by which, in the more perfect animals, it is finally assimilated. This pouch is the *stomach*, and with the rest of the *digestive* apparatus with which it is connected, is in intimate and uniform relationship with the kind of food upon which animals are led by their instincts to live.

All the accessaries of the assimilating cavity or stomach which we find in animals, from the organs of sense that guide them in their choice of aliment, to the lips that seize it, the teeth or jaws that bruise it or destroy its vitality, the muscular actions by which it is swallowed, and the chemico-vital processes by which it is dissolved, and the purely vital sensibilities by which such parts as are proper for nourishment are retained, and such as are improper for this purpose are expelled,—all of these are wanting among vegetables.

There are yet other processes which form an essential item in the acts by which organized beings universally continue their existence, which it is necessary we should include in this summary of the common, particular, and distinguishing attributes of vegetables and animals. One of the most important of these is

Respiration.—The leaves in the more perfect vegetables are the instruments of respiration; their place is supplied by the general surface in those plants that are aphyllous. Vegetables that live in air act immediately by means of their respiratory organs upon the ambient medium; those that live in water, upon the air held in solution by the fluid around them.

Vegetables are well known to *exhale* abundantly from the surface of their leaves, or stems, in case they have no leaves. The matter exhaled is principally water. They have also the farther property of decomposing one of the elements of atmospheric air, namely, carbonic acid gas. In the sunshine the leaves of vegetables fix the carbon which enters into the composition of this gas, and set the oxygen at liberty; in the dark, however, a very different process goes forward; they then actually absorb oxygen and exhale carbonic acid gas; the balance, however, in the aggregate is not equal between these opposite processes, a much larger quantity of carbon being fixed by the decomposition of carbonic acid gas and oxygen set at liberty, than there is of oxygen absorbed and carbonic acid gas set free. These acts are essential to the life and health of vegetables; their end and object appear to be the preparation of their proper nutritive fluids or cambium: the sap which reached the leaves, colourless, not coagulable, without globules, mere water holding carbonic acid, acetic acid, a muco-saccharine matter, and various salts in solution, is in them converted into a greenish fluid, partly coagulable, and full of globules, which special vessels then distribute for the growth and maintenance of the different parts.

The respiratory act is necessary, and goes on without the aid or concurrence of the individual among vegetables.

Animals are no less dependent than vegetables on communication with the air of the atmosphere, either immediately or mediately, for a continuance of their existence, or the manifestation of those acts whose sum constitutes their lives. In the very lowest tribes the communication between them and the air of the atmosphere takes place over the surface of the body generally, without the intermede of any particular organ or organs for the purpose. The fluids absorbed into their bodies are brought into contact with the atmospheric air in those points where they approach the external surface, and there appear to undergo the changes necessary to fit them for being converted into the substance of the animals themselves. Simple as this process may appear, slender as the means of accomplishing it may seem to be, it is nevertheless *essential*: interrupted for any length of time, the animal inevitably perishes. A process of such importance, as may be imagined, is not long left without its appropriate and special apparatus. This varies extremely in its structure, in the different tribes of animals, and according to the circumstances surrounded by which they live. Some have lungs, branchiæ or gills, and tracheæ opening by spiracula, of infinitely varied construction.

Respiration is also carried on vicariously in a very large proportion of animals, if not perhaps in all to a certain extent, by means of the skin, and in some even by the instrumentality of the alimentary canal.

The changes effected in the atmospheric air by the respiratory apparatus of all animals are similar, but they differ from those that are produced by the corresponding implements in vegetables: the proportion of oxygen it contains universally diminishes, and the quantity of carbonic acid gas it holds in solution as invariably increases in amount. A quantity of water or of watery vapour is at the same time thrown off. This is exactly the opposite of what we have seen to be the effect of respiration among vegetables; in these the quantity of oxygen is augmented, whilst that of carbonic acid gas is diminished. The nutritive fluids newly prepared by the apparatus of digestion, or that have already gone the round of the system, are by a variety of means exposed, in the special or common apparatuses mentioned, to the influence of the atmospheric air, from the contact of which they undergo certain important and often manifest changes that fit them for their ultimate office in the animal economy, — the maintenance of its parts, with their inherent capacities to execute the various functions imposed upon them.

The respiratory act among animals takes place with the knowledge and with the assistance and implied will of the individual. Animals are informed of the necessity of respiring by the feeling of a want, an uneasiness, just as they are admonished of the necessity of taking aliment by the painful sensations denominated hunger and thirst.

The essence of respiration in the two grand classes of organized beings would therefore appear to be different, and might be made the ground of a definitive distinction between the members of each kingdom. *Carbon* is the object for which the respiration of plants is instituted; *oxygen* the end for which relations are established between animals and the atmosphere. Another grand difference between the respiration of plants and animals is the involuntariness of the act in the one, and its voluntariness in the other, its occurrence with unconsciousness in the one, and with consciousness in the other.

The nutrient juices thus prepared have now to be distributed; this is done by means of a peculiar motion impressed upon the fluids in virtue of a vital law with the nature of which we are still very imperfectly acquainted. Let us use the word *circulation* in a sense implying motion generally, not motion in a circle to designate the act by which in the organized world the nutritive juices are distributed through the frames of the objects composing it.

Circulation.—There can be no doubt of the existence of a circulation among vegetables; in many species currents in opposite directions have even been seen with the aid of the microscope, and this not only among the lowest and most simple in their structure of the class, but also in the highest and most complicated. The circulation of vegetables appears to take place within two different congeries of vessels, extremely numerous, and disposed according to their nature in different parts of the plant. The vessels that pump or transmit the sap from the roots to the leaves, for instance, as we have already had occasion to state, run within the woody parts of plants; those that receive the modified juices of the leaves, again, take their course downwards within the bark. These two sets of vessels anastomose within the substance of the leaves, but no where else; the second set can alone be said to have a distribution throughout the vegetable, for every part appears to depend on them for its supply of nourishment, even the extreme points of the roots, which were themselves the first instruments in collecting the aliment still unfit for the purposes of nutrition. The best informed vegetable physiologists are of opinion that the nutritive fluid once sent off from the leaves never finds its way back to these orgaus again; it is absorbed or fixed by the different parts or structures to which it is distributed, ministering to their increment generally, and enabling each to manifest its specific function in the vegetable economy.

In this motion of the fluids of vegetables it is evident that there is little analogous to what we find within the bodies of animals somewhat elevated in the scale. But let us first cast a hasty glance at what does take place within this other division of the organic kingdom before instituting a comparison between the functions of circulation in the two. All animals, from the mammalia downwards to the entozoa, —birds, reptiles, fishes, the mollusca, crustacea, arachnida, insecta, and, among the radiata, the holothuriæ, echini, and asteriæ, include within their organisms particular canals or vessels for containing and distributing their nutrient juices, and within which, moreover, these are in motion in a circle. In the acalephæ we still find canals branching off from the digestive cavity and distributing the nourishment there prepared to the different parts of the body: in these, however, we no longer find any contrivance for establishing a circular motion in the nourishing juices. Still lower in the scale, among the polypes and actineæ, for example, we discover no branched appendages or canals for the distribution of the nutrient fluids; those prepared in the stomachs of the animals appear to penetrate their substance directly, and to permeate the homogeneous cellular tissue of which they consist.

In the tribes which have a *circulation*, in the strict sense of that word, we find two orders of vessels,—arteries and veins, in which the nutritive juices, or blood, moves respectively in opposite directions, from the trunks towards the branches in the one, from the branches towards the trunks in the other. These vessels anastomose freely by their extremities, which terminate and originate in every part of the body, and, farther, meet in a common central cavity, which, when furnished with muscular parietes, is entitled *heart*. Within the circle of vessels thus established, the nutrient fluid of animals is in perpetual or next to perpetual motion during the term of their lives. In the higher classes the main agent in producing this motion is the central organ in which the veins and arteries meet; but it is not the only cause of the circulation, this act going on vigorously in circles and in situations wherein the heart's action can have very little influence, and in some tribes where the heart is even altogether wanting.

The circulation in the greater number of animals, however, is a more complicated process than that which has just been described; it consists, in fact, of two parts perfectly distinct from each other; one whereby the blood is exposed to the action of the air in the apparatus which, in connexion with the respiratory process, we have denominated lungs, gills, &c., another by which it is finally distributed for the uses of the system. This double circulation is accomplished by a great variety of contrivances (vide articles Heart and Circulation). In some tribes we find more than one vessel,—two, or three, each apparently independent of the other, though communicating together, which are subservient to the distribution of the nutrient fluid to the different parts of the body of the animal.

The chief differences between vegetables and animals with respect to their circulation, consequently, appear to be these: in vegetables the motion of the sap or aliment takes place through the whole of one of the tissues of which they consist; that of the cambium or proper nutritive fluid through the whole of another of these tissues, in opposite directions simply, and by the intermedium of fasciculated, very numerous, and independent vessels; whereas the aliment of animals does not circulate through their bodies, but the nutritive fluid prepared from it is collected and confined within *peculiar* channels, connected at both extremities in such wise as to form a continuous circle. In vegetables we perceive nothing like tendency towards or distribution from a central reservoir, nothing like ramification from larger to smaller branches, &c.; consequently nothing like a heart, as we do in animals above the very lowest. In vegetables, again, we see nothing like the two-fold distribution of the nutrient fluid within different orders of vessels, the one to the organs of respiration, the other to the system at large, as occurs among all animals possessing a somewhat complicated organization.

We have recognized the heart as the principal cause of the motions performed by the fluids within the bodies of animals; but as neither all animals have a heart and yet exhibit their nutrient fluids in motion; indeed, as a distinct circulation of the blood may be demonstrated in many animals, and probably takes place in all at periods of their evolution anterior to the existence of a heart; and further, as vegetables exhibit a motion or circulation of their fluids without the agency of any special organ, it is necessary to acknowledge a new law by virtue of which the fluids of organized beings generally go their round or reach their destination. This law has been designated as the *propulsive*,—a power inherent in the nutritive globules of living beings, and one of the special laws superadded to the general and all-pervading forces that regulate the universe.

One fundamental distinction between the bodies of the organic and inorganic kingdoms we have found based upon the permanence of the parts, the constancy of the relations, affinities, &c. of the component elements of the one, and the incessant changes or renewals and decompositions which these parts or elements undergo in the other. The various processes by which the aliment of vegetables and animals is converted into a *succus proprius*, the final means of their individual conservation and evolution we have now examined; we have only farther to discover this nutrient juice converted into the different tissues and substances of which organized beings consist, to have a complete view of the vital act of nutrition. But here we are compelled to pause. Of the processes by which this transformation is accomplished we know next to nothing; all we are assured of is, that each tissue and organ seizes upon and converts into its proper substance those particles enveloped in the general mass of circulating fluids brought into relationship with it, and which are adapted to this purpose, at the same time that the particles which have already been consolidated and served their office are reduced to the fluid state, absorbed back into the torrent of the circulation, and afterwards either abstracted and thrown out of the body by the operation of certain organs charged with this duty, or being subjected to the action of the atmospheric air in the lungs, gills, skin, &c. are restored to their fitness once more to enter as temporary constituents of the organization. It is evident, therefore, that we are only acquainted with this operation in its effects. The act of ultimate nutrition has been happily entitled one of continuous generation in each living being and its parts; it takes place in conformity with the laws of vitality instituted, and probably originating and ending in living organized beings.

This subject, however interesting, we must reluctantly forsake, referring to the article on Nutrition, and to the consideration of what has been called the *nisus formations*, or plastic power in our article on Fœtal development.

Vegetables and animals, from this review, appear to differ little from one another in all that regards their *nutrition*. The processes that lead to this conclusion may be, and, indeed, are more complicated among animals than among vegetables; but the essence of the final act is very nearly the same in both. Neither shall we be able to demonstrate any great want of uniformity between these different classes of organized beings in several of the actions which we shall next discuss; in others, however, we shall discover an impassable line of demarcation between them. The first of these actions which we shall consider is

Secretion.—We have already had occasion to mention the watery exhalation and oxygen thrown off by the leaves of vegetables. Divers other substances are excreted by the same parts, —water, various acrid, glutinous, saccharine, and balsamic substances. It is even by means of the leaves that vegetables throw out those substances which they may have absorbed by their roots, and which seemed calculated to injure them. We are at no loss, moreover, to demonstrate numerous apparently glandular organs in vegetables for the elaboration of a variety of substances, many of them very acrid. The flowers of vegetables secrete, in the first place, certain matters, the infinite variety of whose odours proclaims them to be different; the nectaries are also filled with fluids, which are sweet in many tribes. Lastly, in the flowers, the male fecundating matter, and the fluid that moistens the pistillum are secreted. Nor are vegetables without *internal* secretions, among the number of which certain aeriform fluids are not the least curious. The other secretions of vegetables are of infinite variety, —gummy, oleaginous, balsamic, camphoric, &c. &c. These are all stored up in cells contained in different parts of each individual plant, and undoubtedly either subserve important purposes in their several economies, with the nature of which we are very imperfectly acquainted, or are in relation with some other system in the universe, affording food to numerous tribes of insects, or materials which stand in relation to animals and man as means of accomplishing a variety of ends, the impulses to which they bring into the world with them, though they are launched upon existence unfurnished with the materials.

We have also hinted at the watery and gazeous products of the respiration of animals, and consideration for a moment enables us to make a long catalogue of other secretions both with reference to individuals and to species. We have, for instance, the limpid fluids that bedew the cellular and serous membranes, serum and synovia, and fill various cavities in the body—the chambers of the ear and of the eye particularly; those that moisten and defend the surfaces of the mucous membranes, the tears and mucus; those that are subservient to digestion, the saliva, gastric juice, pancreatic juice, and bile; those that lubricate and prevent the surfaces exposed to the air from drying, the sebaceous or oleaginous fluids of the skin, and cerumen of the ears; those that are laid up as reservoirs of nutriment or defences from the cold, the fat, marrow, &c.; those that are the vehicles for the worn-out particles of the body, the urine and perspiration; those that minister to the reproduction of the species, the fluids of the female germ or ovum, the spermatic and prostatic fluids of the male; and finally, those that are poured out among the mammalia as the first aliment for the newly-born being, the milk. Nor is the list exhausted, for numerous species of animals have peculiar fluids which are useful to them in the places they hold in the system of creation; among these are the venomous fluids of serpents, and of the stings of numerous insects, the inky fluid of the cuttle fish, the fetid fluids of the anal glands of the carnivora, rodentia, &c.; the fluid with which spiders weave their web; the wax with which bees build their cells, &c. Secretion is, therefore, a much more extensive function among animals than among vegetables; the products are still more various, and the apparatus by which they are eliminated is, generally speaking, far more complicated among the former than among the latter. Certainly, in the very lowest tribes of animals, secretion is an exceedingly simple process contrasted with what it becomes in the higher, whose organization is more complex. Among the polypi, medusæ, and entozoa, the whole of this function seems to consist in a kind of transudation, or exhalation from the surface of their homogeneous bodies, without the intermedium of any special organ. Among animals higher in the scale we find secretion performed in two modes,—by vessels, when the act is entitled exhalation, and by means of certain special organs named glands, an arrangement which we also find among vegetables. The skin and pulmonary surface are the great implements of exhalation among animals, as the leaves are among vegetables; almost all the rest of the secretions take place by the instrumentality of glands.

In vegetables secretion seems to be limited to the preparation of the nutrient fluid by the elimination of certain matters, and, so far as our knowledge extends of the end to be answered by any act, for the formation of the generative fluids; we do not, in fact, find among vegetables any apparatus set apart for the excretion of matters derived from a change in the constituent particles of the organs once formed. Among animals, again, the apparatus by which this depuration of the system is accomplished is one of the most important of all to the preservation of the individual. Secretion among vegetables is a function much more under the influence of external circumstances than it is among animals; it is also more subject to periodical changes among the former than among the latter, and whilst the function is mostly called into activity by the stimulus of light, heat, &c. in the one, it rather obeys certain internal and peculiar stimuli transmitted through the medium of the nervous system in the other.

Like all the other special modes of activity manifested by organized beings, secretion is one of the products of the laws of vitality with the essence of which we are altogether unacquainted.

Besides the secretion of the various gaseous, fluid and solid matters mentioned, vegetables and animals appear in common to possess the power of disengaging certain imponderable elements—heat, light, and electricity.

Heat.—There has been considerable variety of opinion among physiologists with regard to the extent to which vegetables have the power of maintaining a temperature of their own independently of that of the surrounding media. Nor is this question, in our opinion, yet completely set at rest. It is certain that trees in high northern latitudes endure a cold many degrees below zero without injury, whilst in intertropical countries they are frequently exposed even in the shade to a heat above that of any animal without perishing; actual experiment, indeed, proves that they preserve a temperature intermediate between that of the extreme heat and extreme cold of the diurnal variations of those latitudes in which they are indigenous. This circumstance is explained variously, some attributing it to a vital property in plants to regulate to a certain extent their own temperature, others alleging that it is merely owing to the indifferent conducting qualities of the materials of which vegetables are composed. The thermometer has been seen several degrees below the freezing point of water within the trunks of fir trees, without their vitality being affected; but it is probable that the constitution of this tribe renders them capable of enduring such a reduction of temperature with impunity as would prove fatal to other trees with simple watery sap.

On the other hand, it is quite certain that the flowers of many vegetables have the power of disengaging heat, a difference of ten, twenty, and even more than thirty degrees having been observed at sun-rise between the temperature of the atmosphere and that of the flowers of different vegetables in southern latitudes, and the same thing is known to occur, though to a less extent, in northern countries.

It would therefore be unfair, with such facts before us, to deny altogether to vegetables the faculty of disengaging caloric. Arguments, indeed, *à priori*, might be adduced to show that they must almost necessarily possess such a property: they are the subjects of incessant change; and one of the most universal of the physical laws involves a change of temperature on any change of constitution.

If the faculty of vegetables generally to secrete or eliminate caloric be doubtful, however, it is indisputable that among all animals a little raised above those at the very bottom of the scale, there is an inherent power of generating caloric, which in their state of maturity is nearly determinate as regards each particular species. Mammalia and birds have universally the highest temperatures.

Reptiles or cold-blooded animals, as they are improperly called, have also the power of engendering heat, and of regulating their own temperature: this faculty, however, and the degree of heat they possess at different times, are influenced to a very considerable degree by the heat of the media in which they live. The same statements may be made with regard to fishes. The temperature of these creatures is generally several degrees above that of the water they inhabit; but it also varies with the temperature of their native element.

Many insects have a very decided power of engendering heat and of regulating their temperature; and similar faculties have been demonstrated in the crustacea, the mollusca, and the annelida. These tribes, however, are all very much influenced by the temperature of the media surrounded by which they live.

No great difference is therefore discernible between vegetables and animals in the faculties they possess of engendering caloric and regulating their own temperature; the faculty is only much more decided, and possessed to a far greater extent among the more perfect classes of animals generally than among vegetables at large. It may very fairly, in the present state of our knowledge, be ascribed as a common property.

As to the mode in which heat is engendered, opinions are still very much divided. The chemical and mechanical explanations that have been given of the phenomenon are not universally applicable. All we can say at the present day is that the production of heat and the power of regulating their temperature possessed by organized beings is another of the hidden and singular laws or properties introduced into the system of the universe with their creation.

Light.—Many unorganized bodies have the property of shining or giving out light for some time after they have been exposed to the bright rays of the sun, or have been heated in the fire, or when they are struck together or smartly compressed, and this certainly without any decomposition of their substance. The disengagement of light, again, is a very uniform accompaniment of the decomposition and composition of inorganic substances, and it appears to be a very constant attendant upon electrical phenomena.

Various organic substances and products of organization have a similar property; living vegetables, too, particularly the flowers, have been seen to give out light by authorities so respectable, that though the fact has been called in question by others of great name, there seems no sufficient reason for treating all that has been said on the subject as illusion: in the physical sciences negatives cannot be received as evidence of equal value with positives.

No one thinks of calling in question the luminousness of animals; most of the innumerable inferior tribes that live in the sea, appear to possess and to manifest this property at different seasons. The luminousness of the ocean itself, so familiarly known, seems to depend on the presence of multitudes of infusory animals within its bosom. Many tribes of insects shine in the dark. The phenomenon is not certainly known to be manifested by any of the class of reptiles, birds, or mammalia. It appears to depend, in insects particularly, on the presence of a peculiar matter, secreted by their bodies and stored up in particular points, which, under the influence of a temperature elevated in a certain degree, and the contact of atmospheric air, enters into a kind of combustion during which light is emitted. Is the phenomenon dependent on one common cause in both vegetables and animals, supposing that it does really occur among the former?

Electrical phenomena are extensively exhibited by the objects composing the unorganized and the organized world. In fact, wherever there is composition and decomposition going on, there are electrical phenomena manifested. The action of the immense mass of vegetables on the air, the evolution of oxygen in the sunshine, and the formation of carbonic acid during the dark, has even been supposed by an ingenious natural philosopher of France (Pouillet) to be the principal source of the electricity of the atmosphere.

Galvanic electricity is excited by the contact of the different parts of which animal bodies consist, particularly of the nerves and muscular flesh; the nerve of a frog's thigh exposed and isolated, touched with a piece of quivering flesh from the body of a bullock just slain, also isolated, causes the muscles to which the nerve is distributed to contract energetically (Humboldt). The same phenomenon occurs when different other parts and fluids, particularly the blood, are used to form a chain. But the electrical phenomena manifested by animals at large, are weak when contrasted with those exhibited by certain fishes provided with special voltaic piles or galvanic batteries by which they give at will, but not otherwise, electrical shocks of such violence as to stun larger animals and even to deprive smaller ones of life. This electricity of animals must be held as a vital phenomenon; several of them have indeed a peculiar apparatus for the preparation of the shock, to speak of the phenomenon by its effects, in our ignorance of its essence or efficient cause, but this loses its power when the nerves that are abundantly distributed to it are divided.

Electrical phenomena are not so obviously displayed by any other tribe of animals as by fishes; but it has been rendered next to certain that muscular contractions are uniformly accompanied by a kind of electrical discharge from the nervous fibrils distributed to the special organs of voluntary motion.

Animals, from this brief review, appear to possess electrical capacities in a much higher degree than vegetables, in which the phenomenon is even explicable on ordinary chemical principles, whilst among animals it is unquestionably one of the effects of vitality.

We have already indicated the existence of two faculties among animals which become necessary or complemental to them as agents entrusted with their preservation as individuals, and their continuation as kinds; these are voluntary motion and sensation. But motion in the abstract is a phenomenon of much more extensive occurrence among organized beings than the notion we form of the act as connected with the existence of a muscular system. Motion is in fact a quality inherent in organized beings; they cannot be conceived as existing without change, and change implies motion. In most, or indeed in the whole of the actions which we have glanced at as manifested by them, we have supposed motion. The simplest of all animals, the infusoria, move about in many cases with great briskness; the polypes, composed of an uniform gelatinous mass, also move in various directions; the acalephs, with a similar structure, rise from the bottom and propel themselves through the waters of the ocean by a succession of contractions of their disc, of their tentacula, or of the fringe-like or foliaceous bodies with which several orders of the genus are provided. Many of the entozoa too, whose bodies consist of a simple gelatinous or mucous tissue, execute motions in various senses.

But it is not only as a whole that a body endowed with life and organization possesses a capacity of motion. Many of its parts, and particularly the globules which enter as essential and integral parts of the fluids contained in organized bodies, have inherent powers of motion: the globules of the blood, for instance, those of the spermatic fluid, and perhaps also the germ included within the ova of the polype, mollusc, &c., have all been observed in motion, and the means by which it is accomplished even demonstrated in many cases. But there is nothing absolutely peculiar in such individual instances, for we must need conceive motion in the first constituent elements of all organisms without exception, long before a muscular, a cellular, a nervous, or any other distinct system has existence.*

Motion of all kinds, therefore, automatic as well as that which is voluntary, must be held as a quality inherent in organized or living beings. The cause of this phenomenon, as of so many others manifested in the world of organization, has been the subject of much difference of opinion and of much dispute among physiologists, and many titles have been imagined by which the agent or primary cause of the act has been sought to be designated, or the act itself to be explained.

It is quite certain that the capacity to commence and to continue the phenomena which we designate as vital, or the motions which constitute these phenomena, depends first on a variety of external conditions, such as a

* Such motion is indubitable. The organic globule has capacities of motion inherent in itself, different from the motions of unorganized objects in a state of extreme division, as is proved by the motions of each kind of body being different, and those of organized globules being interrupted by the electric spark, or whatever destroys their vitality —acids, alkalis, poisons, &c.

certain temperature, intercourse with the air of the atmosphere, supplies of aliment, and the access of light, and it is indubitable that organized beings exhibit phenomena that may be designated excitability, irritability, vital force, &c., which are only other names for these manifestations; but it is also certain that external conditions are of themselves inadequate to originate manifestations of vitality, and that the phenomena of living organized beings, generally designated excitability, irritability, incitability, &c., are *consequences* of a state of things to explain which they have been conceived as *causes*, under the title of *life*, *vital principle*, *soul*, &c. The term *excitability* should be used in physiology, in the very widest sense, to signify a property inherent in organized matter generally, to be determined to manifestations of activity under and in conformity with external influences (Tiedemann). We in fact see organized matter of every description—the green matter of Priestley, confervæ, infusory animals, &c., acquiring organic forms under the dominion of outward influences, and every species of organized being existing within a determinate circle of external agency.

It were a grave mistake to suppose this agency either *chemical* or *mechanical* in its nature; when of such potency as to act either chemically or mechanically it is destructive instead of productive of vital phenomena. These phenomena, therefore, and external influences are rather in opposition to one another than identical. External influences excite organized beings to manifest their inherent capacities; they do not bestow these capacities; all organized beings, indeed, and each particular tissue of every individual among them, are excited in different modes by the various influences from without; the stimulus is identical, the effects are infinitely different.

But organized beings, and especially animals, are not dependent on external influences alone for the manifestation of their peculiar properties; they have themselves the additional power of engendering stimuli proper to arouse into activity the various organs and systems of which they are composed. The fluids circulating through every part of their bodies may be regarded in the light of the most generally distributed stimuli of this description. The nrevous system is another and important source of excitation, the influence of which is felt in every part of the organism of all animals above the very lowest. The various instincts, appetites, propensities, sentiments, and intellectual faculties, also, which all emanate from the nervous system, are inherent causes of a vast variety of manifestations of activity among the more perfect animals. There are yet other stimuli of a mechanical, or chemical, or peculiar nature, which excite unusual or anomalous manifestations; in this category may be placed contagions of different kinds, the causes of epidemic diseases, medicines, &c.

With regard to the essence or cause of this property of the organic globule to commence, and of the perfectly developed organism to manifest the various phenomena whose sum constitutes their vitality, and endows them with their various cognizable properties, all we can say is that it appears to inhere immediately in the particular state of matter which composes them. What this state is in itself we cannot tell; but we are familiar with the phenomena which ensue from, and which indeed reveal to us its existence. It is evidently as diversified as species, and as the systems or organs possessed by the individuals severally composing these: there is a power—the *nisus formations*, the *vis plastica*, in the matter susceptible of formation,—the *organic globule*, the *germ*,—which presides over and regulates its acts; and there are powers inherent in the parts or organisms to which the plastic force gives rise, in accordance with which they manifest the special acts that distinguish them. It would be improper, however, to regard this power or these powers as forces apart from and other than the globules, germs or organisms themselves; in the present state of our knowledge we cannot separate exciting causes from manifestations of activity; all we can venture to say is that germs exist, that organisms exist with inherent capacities of action in harmony with the peculiar states of their constituent elements, thus: the germ of the infusory animal exists with its inherent capacity to engender an infusory animal, the germ of the polype with its inherent power to produce a polype; in the same way the various tissues, vessels, glands, &c. of vegetables and animals exist with their special capacities of excitation, which are manifested in the particular functions they severally perform. Excitability is therefore a multiform property and a consequence, not a single peculiar power inherent in organized beings, the fundamental cause of their actions and identical with or itself the living principle. Dependent on the integrity and continuance of the functions of nutrition, how can it be the cause of these? Only manifested in kind, with the occurrence of specific organs, how can it be the cause of their several manifestations?

We are altogether in the dark with regard to the mode in which the motions and other actions of organized beings are performed, how or by what law the globule that in the infusion of organic matter is to become an infusory animal moves, as well as of the manner in which the contractility of a muscle is excited by the stimuli fitted to call this quality into action. The contractility of the infusoria, polypi, medusæ, and other similar tribes appears to be peculiar. The motions exhibited by the confervæ, tremellæ, and simplest vegetables are also peculiar to them, they differ from those manifested by the simplest animals in being entirely under the influence of external influences, and showing nothing like spontaneity. The tissues of all animals, even the most complicated, show traces of a vital tension or contractility, different from simple elasticity and not depending on muscularity; the cellular membrane, skin, fibrous tissues generally, excretory ducts, and vessels of all descriptions tend to contract upon the parts and fluids they surround and include. This tonicity or peculiar contractility disappears in great part with the cessation of life: a wound made in a dead body never gapes as it does in a living one. Something of the same kind exists in vegetables; the sap ascends with greatly increased velocity in the young shoots under the influence of stimuli of different kinds, and its flow is checked by narcotics and altogether arrested by poisons; it is probable, therefore, that it takes place in consequence of a vital tonicity or contractility in the sides of the sap-vessels which contain it.

From this general review of the physical construction and vital phenomena of the two grand classes of organized beings, vegetables and animals, it is impossible not to remark the strong features of resemblance, and yet the numerous points of difference they exhibit. Both have a beginning, which happens very much in the same way in each; both live as individuals by the susception of aliment and its prepration by a variety of processes, which, in their essence, differ but little from one another; both continue themselves as kinds in a surprisingly similar manner; both exhibit the changes denominated age; both have a merely temporary existence, consequently both exhibit the phenomenon entitled death, and both are decompounded after the cessation of life, their constituent elements assuming new shapes, in obedience to the general laws of chemical affinity, which had been set at nought during the existence of the individuals in either class.

Notwithstanding these striking points of resemblance between vegetables and animals in all that is essential or general, it is impossible, as we have seen, to condescend upou particulars without immediately detecting differences that distinguish in the most marked manner the individuals of the one class from those of the other. It is always in their lowest or most simple species that we remark the most striking similarity between vegetables and animals, and it is among these that we constantly find ourselves most at a loss for characters distinctive of each. We observe no evidence of anything like a connected chain of being from the lowest or most simple, to the highest or most complicated vegetable, and from this through the most inferior animal upwards to man; it is, on the contrary, in the extremes or lowest grades of each that the greatest similarity prevails; here vegetables and animals approximate very closely, here they literally inosculate, but from this common point they begin to form two distinct series, which diverge ever more and more widely from one another as they ascend. Without attention to particulars, it would seem impossible to adduce as ultimate terms of distinction between vegetables and animals, other faculties than those of voluntary motion and sensation as peculiar to the latter, in virtue of the one of which powers they are rendered in a great measure masters of their own existence, whilst by the other they are endowed with consciousness of many of the various acts that take place within, and of the phenomena that occur without them. Even this distinction, however, is only applicable as regards species considerably raised above the lowest; would we indicate the differences between the most inferior members of either series we must condescend upon particulars, and, in some instances, even call in analogy and inference to our aid in laying down the chart of their resemblances and dissimilarities.

COMPARISON OF ANIMALS WITH ONE ANOTHER.

This head is also comprised within that of our entire Cyclopædia. The glance we shall cast over the field it embraces will, therefore, be very cursory, and the views taken of the objects it presents extremely general.

Physical qualities and material constitution of animals.—In point of *size*, animals differ most widely from one another. The existence of some is only made known by the aid of a powerful microscope, the length of others exceeds a hundred feet, and their weight amounts to many tons. These extremes include animals of every intermediate bulk.

The *form* assumed by animals presents many more interesting particulars for study and investigation than the mere bulk of their bodies. The consideration of this accident has even been made the ground of a classification of the objects included within the animal kingdom by several naturalists, and although not adopted as the sole basis of any one now generally received, it nevertheless furnishes the element upon which several of the classes even of the most recent are established. Some animals present themselves in the likeness of a *globule*, others of a *filament*, and others of a small *flattened* membrane (the cyclides). Various animals, again, from exhibiting no uniform or regular shape, have been entitled *amorphous* or *heteramorphous*.

Animals which exhibit a determinate form naturally arrange themselves into two classes; their bodies are either disposed around a centre, or they consist of two similar halves cohering along a middle plane or axis; the first are the *radiata*, the second the *binaria* or *symmetrica* of naturalists. The radiata are not a very extensive class of animals, neither is their organization extremely complicated. The symmetrical is a much more numerous class than the radiated, and includes within its limits creatures of such simple structure as the entozoa, and of such complicated fabric as quadrupeds and man. Of the symmetrical animals, some consist of a mere trunk without appendices or limbs; those that are provided with limbs, again, have them in the shape of feet, fins, wings, or hands, according to the media in which they live. In some the body forms as it were a single piece, in others it is divided into portions, such as head, trunk, and tail. Sometimes it is naked; at others it is covered with shells, scales, spines, hair, &c. Sometimes the general integument is continuous, unpierced by any opening that leads to the interior, at others it is reflected inwards, and lines extensive cavities there contained.

With regard to *structure*, as may be imagined, the amorphous tribes, at the bottom of the scale, are the most simple of all. The bodies of some of these are without any internal cavity, and without any division of parts; they are homogeneous masses, generally gelatinous in appearance, and simply cellular in structure, without arrangement into tissues or particular organs. The external surface of these animals imbibes the matters which are fitted to subserve the purposes of nutrition, and we may presume that it throws off by transpiration such particles as are worn out or have accomplished this end. The external surface is also the organ of respiration in these animals. They procreate by the evolution of gemmi from their surface, and if they possess sensibility the element to which it is attached must be generally diffused throughout their substance.

The organization of the radiata becomes considerably more complicated. Fluids are no longer absorbed from the external surface of the body; we meet with an internal cavity, the rudiment of a digestive apparatus, having a single opening in some of the species, which serves consequently for both mouth and anus, but in others presenting two openings, a mouth properly so called on one side of the body, and an anus on the other. Through the walls of this cavity the nutritive fluids make their way, and infiltrate the general mass of the animal's body. In this class we also discover the rudiments of a nervous and of a muscular system. The nervous system consists of rounded masses of a soft whitish substance, equal in number to that of the radii composing the animal, connected together by slender white cords, and sending off filaments of the same description to all parts of the body, but especially to the outer integument, and to the internal digestive apparatus. The muscular system consists of reddish and whitish fasciculated fibres disposed in the line of the motions. The external surface of these animals is still the only organ of respiration they possess.

The three systems now enumerated—the digestive, the nervous, and the muscular—are readily demonstrated in the majority of the symmetrical animals, and are even very soon found to have acquired complication, and to have sundry other parts and organs superadded to them. The digestive apparatus consists of a mouth for the susception of aliment, of a stomach for its elaboration, of an intestinal canal from which the nutrient juices are absorbed, and of an anus from which the undigested residue is expelled. Whilst in the radiata the nutritious fluids passed through the parietes of the digestive cavity to impregnate the body of the animal, and be assimilated with its substance; in the binaria we find vessels, the rudiments of a circulating system, employed in receiving the juices prepared in the digestive apparatus and transmitting these to all parts of the body. Digestion, too, in this class becomes a more complicated process than in the radiata, and various secreted fluids, *saliva* and particularly *bile*, the special products of large and evidently important organs, are added to the alimentary mass in its progress through the intestinal canal.

In addition to the digestive apparatus and general external respiratory surface we by-and-by find an especial system dedicated to the aeration of the juices prepared for nutrition; this is the *respiratory apparatus*. Of extreme simplicity in the first instance, being little or no more than a fold of integument turned inwards, and forming a simple cavity or sac within the body of the animal, it is soon rendered more complex in its structure, being distributed in the manner of vessels under the name of *tracheæ* or *canals* to different parts of the body, or being confined to a particular district, and entitled *lungs* or *gills* as it is fitted to receive the atmospheric air immediately, or to make use of this elastic fluid suspended or dissolved in water.

The existence of this separate respiratory apparatus presupposes that of another system, namely, the *circulatory*. The fluids prepared by the organs of digestion are not yet fitted to minister to the growth and nutrition of the organization; to be made apt for this purpose they require exposure to the air in the lungs or gills wherever these organs exist, and these being distinct, or contained in a particular region of the body, a series of conduits were required, first to carry the fluids thither, and to transmit them subsequently to every part of the organization for its support. Like all the other systems of animals, the circulatory exists of various degrees of complexness; when first encountered it consists of a series of simple canals or vessels, which diverge on every hand; by-and-by it has several, and finally one, forcing piece, or heart superadded to it, which impels the fluids by its contractions to every the most remote part of the organization.

Among animals, however, nutrition is not a process simply of addition or composition; it is also, perhaps universally, one of subtraction or of decomposition. We have seen the composition provided for by special systems in animals occupying very low grades in the scale of creation; we mount but a short way before we encounter an apparatus which presides over the decomposition also in the shape of another system of vessels, the *veins* and especially the *lymphatics;* these collect the superfluous and worn-out particles from every part, pour them into the general current of the circulation, wherein being exposed in the vital elaboratory of the lungs they are either assimilated anew and made fit once more to form an integral part of the organization, or, being subjected to the action of certain glands, they are singled out, abstracted, and finally ejected from the system entirely. In the most complicated animals therefore a peculiar apparatus for the depuration of the system is superadded as complementary to the absorbents. This we find in the glandular bodies familiarly known as the *kidneys;* the vehicle in which the decayed particles are withdrawn is the urine.

When we examine the instruments of *sensation*, we find them becoming gradually more and more numerous, and the nervous system generally more and more complicated as we rise in the scale of animal creation. The nervous system is before long found to consist of other parts than a series of similar ganglions supplying at once the organs of sensation and those of digestion; it has a central part superadded, from which issue immediately the nerves that supply the organs of the senses,—sight, hearing, taste, and smell, which at the same time make their appearance with their especial capacities. This central superadded portion is the *brain*, with its prolongation in the vertebrata entitled *spinal marrow*. Nor in the more perfect classes of the animal kingdom is the nervous system even thus simple; among them it consists essentially of two grand divisions, the one including the brain and spinal cord and the nerves thence proceeding, the other constituted by the system of the *great sympathetic*, or that series of ganglions which, situated on either side of the vertebral column, from the head to the pelvis, are connected with one another, and with the cerebro-spinal system, by branches of communication, and furnish the digestive apparatus with almost the whole of the numerous nerves it receives.

The nervous system in its relative degree of development and complexity becomes the ultimate standard by which the perfection of animals is estimated, and their place in the scale of creation assigned to them: if man stand alone and unattended, as he undoubtedly does, upon the summit of the pyramid, it is only because he possesses in his brain the organs of certain moral and intellectual faculties which occur in no other living thing; these confer on him his humanity; these are the material parts to which the soul is wedded during his existence.

In intimate connection with the functions of phrenic or animal life, and developed nearly in the same ratio, is the *muscular system*, the most universal agent of locomotion. Exceedingly simple at first, and operating at great disadvantage through a want of levers and points of support, we trace it becoming gradually more complicated as we ascend, and, finally, provided with a complementary *skeleton* or frame-work by means of which it acts to the best advantage. The skeleton among animals is of two kinds,—external and horny, internal and osseous. In the first case the muscular system is inclosed within the resisting pieces which it has to move; in the second it is without these, and is arranged around them. The bones and muscles together compose the numerous and variously fashioned instruments with which animals accomplish the promptings of their inward appetites and instincts. They form feet, fins, hands, the prehensile tail, &c. The muscular system, and a modification of the osseous, the cartilaginous, moreover, compose the most universal instrument by which animals communicate their vicinity, their states, their dispositions or affectious, &c. to one another—this is the *larynx*.

The means by which species are continued, are extremely varied. The very lowest tribes of animals we have seen shooting forth buds exactly like vegetables, and these being in due season detached from the body of the parent, find themselves fitted to commence an independent existence. At the next step we take in ascent, however, we meet with particular organs of reproduction; and, singular enough, the moment these exist they are not of one, but of two kinds, denominated male and female. Sometimes these organs are possessed by single individuals, far more commonly, however, they are divided between two, whence the so uniform division of the beings composing the animal kingdom into sexes. The simplest form of the male organ of generation is a gland secreting a fecundating fluid (the testis) and an excretory duct: the simplest form of the female apparatus of generation is a gland or body producing germs (the ovary) and an excretory duct. In a greater state of complication or development these essential parts in the male have an instrument superadded to them by which the fecundating fluid is carried directly into the body of the female, and in the female the ovary has a dilatable cavity superadded in which the germ remains for a season, and until its included embryo attains such a state of development as is compatible with its more independent existence surrounded by the circumstances amid which it is afterwards to live. In the higher classes, the connection between the parent and offspring does not cease immediately on the birth of the latter, and in the highest of all we find the female furnished with a complementary apparatus (the mammæ), from which she furnishes her young with food during the first period of its existence.

Actions of animals.—The foregoing rapid sketch of the grand features of distinction among animals with reference to their structure naturally leads to the inference of diversity of function in harmony with the peculiar organization possessed by each. In the lowest grades of animal existence we have seen to how simple a process the act of nutrition—this act so complicated among the more elevated tribes,—is reduced. It consists merely of imbibition or absorption by and of exhalation from the general surface of the body. The matters absorbed appear to be assimilated incontinently, or to be made a part of, and to receive the form proper to, the animal in the instant of their assumption: applied immediately to the homogeneous organism, the nutriment is forthwith made a portion of its substance. The vital decomposition of the bodies of these lower animals is accomplished with the same simplicity and directness: the surface that absorbs is also that which exhales the worn-out particles of the system.

The first step by which nutrition becomes more complex, as we rise in the scale of creation, is the institution of a process of solution (digestion), by which the matters appropriated as aliment are prepared for reception into the body. This process of solution is accomplished by powers inherent in the animal itself, within a cavity destined for the purpose. In our survey of the structure we have already seen to how great an extent the organization became complicated as a consequence of this centralization of the office of digestion, and with what variety of superadded function this complication was attended, namely, *external absorption*, *sanguification* or the formation of a fluid, the pabulum of nutrition, confined within vessels, *respiration*, *circulation*, and, finally, *assimilation*, in regard to the composition; whilst with reference to the vital decompositions we have discovered another species of interstitial or *internal absorption*, and *depuration* of the system by one principal apparatus, the kidney, to which the cutaneous and pulmonary exhalations may be added as supplementary.

But every one of these functions, and its organic apparatus, are themselves modified, according to internal aptitude, and in conformity with the circumstances surrounded by which animals commence and continue their existence. *Digestion* is a very simple process in those cases in which it takes place within a single cavity, having but one opening, and no complementary apparatus of any kind, compared with what it is when connected with an apparatus for bruising the food, for mixing it with saliva, for macerating it in a crop or a series of reticulated and foliaceous pouches, mixing it with bile, pancreatic juice, &c. &c., and transmitting it along a muscular canal, of six, eight, or ten times the length of the body to which it belongs.

Absorption, in like manner, among the most inferior classes is essentially one and undivided either in kind or destination. It is in itself adequate to the entire office of nutrition, seizing and transmitting the matters which are fitted for this end, elaborating the food and atmospheric air at the same instant of time, and effecting immediately the composition of the whole animal organism. In animals higher in the scale, we perceive, in the first place, that there are several species of absorption: there is, in the first place, the absorption from the surface of the digestive passages and that from the surface of the lungs, gills, skin, &c. or of the respiratory apparatus. Again, absorption is not limited to furnishing materials for the composition of the organism; it is also entrusted with the office of abstracting from its interior the particles which are worn out and no longer fit to continue the ends of their existence in the places they occupy. Nor is this all; for it is by absorption that the amount of those exhaled fluids which moisten internal cavities, having no external communications, is regulated, and by which, as it would appear, many of the secreted fluids, the bile, and the spermatic fluid in particular, are inspissated and rendered more fit to accomplish the important ends they subserve in the economy. Absorption in the highest classes of all is even performed by two, and perhaps three different orders of vessels, the lacteals, namely, the lymphatics, and the veins.

Further, absorption is not in the higher as it is in the lower classes of animals a function effecting immediately the composition and decomposition of the parts and particles of the organization. It is intermediate to the preparation of the nutritious juices and their appropriation or assimilation by the organism. The lacteals or absorbent vessels of the intestines collect the fluid called *chyle* from the pultaceous alimentary mass in its progress through the intestines. But this fluid is not yet fitted to subserve nutrition; as a preliminary it has to be subjected to the action of the atmospheric air in the gills, lungs, &c., where, being converted into arterial blood, it first becomes apt to minister to the growth and reparation of the body and its parts. So also in regard to decomposition: the fluids collected from all parts by the lymphatics and veins, are not immediately rejected from the economy, as useless and having already accomplished all of which they are susceptible, but being first exposed to the contact of the atmosphere, and then made to undergo the scrutiny of the depurative organs, they are either retained, being restored to their pristine capacity to subserve nutrition, or are abstracted from and thrown out of the body as no longer fit to aid in its growth and maintenance.

Intercourse with the air of the atmosphere is essential to every living thing, and we should *à priori* have anticipated very considerable variety in the means by which, as well as the mode in which this intercourse is established. Among the inferior tribes which are nourished by absorption immediately from the surface of their body, and which find the materials of their nutrition ready prepared for their use in the circumambient media, we may presume that the matters absorbed have either undergone the needful changes by exposure to the air previously to their assumption, or that these changes take place at the time they are appropriated. Where digestion is a preliminary to absorption and assimilation, it is evident that this could not have been the case; and hence the necessity for that modification of the function of *aeration* entitled *respiration*. Looking generally, we observe two principal varieties in the mode by which aeration is accomplished: in some classes there are a number of holes arranged symmetrically along the sides, and communicating with air-vessels entitled tracheæ, which are subsequently distributed to every part of the body. The air in this case is evidently brought into communication with the nutrient juices already arrived at their destinations; and the necessary changes are wrought in them at the instant of their assimilation. Here the respiration is very properly said to be *diffuse* or *disseminated*. In other classes, again, in which the respiration is *local* or *concentrated*, in harmony with the existence of a special apparatus, which we have spoken of under the title of lung or gill, aeration is accomplished by the access of the air on the one hand, and the exposure to its action of the nutritive fluid on the other, the effect of which is to convert the latter into arterial blood, and to make it fit, upon its distribution by appropriate channels, to accomplish the ultimate and immediate nourishment of every part of the organization.

The differeut media in which animals live involves the supposition of another modification as to the mode in which the blood or nutritive fluid is aerated. Those that live in air respire this elastic fluid immediately; those that live in water, again, respire it mingled with or dissolved in the surrounding medium. The tracheæ of those animals whose respiration is diffuse, and that exist on the surface of the earth, consequently are filled with air; those of the creatures that exist in water are conduits for the constant transmission of this fluid. When the respiration is concentrated, corresponding modifications in the function are encountered according to the medium in which animals live: the air is either received immediately into the body, when the apparatus is known as a *lung*, or, suspended among water, it is passed over the surface of the respiratory organ, which is then denominated *gill*. Quadrupeds and birds respire universally by means of lungs, fishes and the mollusca by means of gills. In certain reptiles the function is carried on by means both of lungs and gills, and as it would appear even by the general surface of the body either vicariously, or at one and the same time. These are the only true amphibious animals.

A *circulation*, properly so called, is the appanage of an organization already somewhat complicated, consequently of an animal considerably raised in the scale of creation. This function, it is evident, as implying in its simplest sense a progressive motion of the general nutritive fluid or blood, can only exist where such a fluid is encountered. It is altogether wanting, therefore, among those animals in which nutrition is accomplished immediately. We ascend but a little way in the scale before we find the function consisting not only of an outward or progressive motion of the nutritive fluids, but of a retrograde motion also of these same fluids modified in their nature, and requiring exposure to a greater or less degree in some form of respiratory apparatus to fit them anew for distribution to the organization at large. The fluid in this instance parts from a centre, and returns thither after having made the round of the system. Circulation in this acceptation only occurs among those animals that have a separate respiratory apparatus, and in which we meet with absorption of nutriment from without, and of lymph, &c. from within. The pabulum of nutrition is taken up by lacteals and veins from the digestive apparatus, and by veins and lymphatics from the rest of the organism for transmission, under the name of venous blood, to the apparatus of respiration, whatever its form. In this the fluid, still immature and unapt for assimilation, is exposed in vessels of infinite minuteness and extreme tenuity to the action of the atmospheric air, and having undergone in these a certain change, it begins to be collected by another set of vessels, which form branches successively of larger and larger size, until finally it is projected from the respiratory apparatus in one or more trunks, under the name of arterial blood, fitted for assimilation by the organization at large, and proving the principal stimulus under the influence of which its various particular organs accomplish their offices.

Circulation, however, as a function, is complicated in the same degree as the apparatus by which it is effected. In some classes we find the circulation taking placing through *vessels only*, one set distributing the blood from the respiratory apparatus to the body generally, another collecting this fluid again, and the newly-absorbed matters from the body at large, and transmitting these for elaboration anew in the organ of respiration. In other tribes, and this invariably after the very lowest grades of the scale are passed, we find the hollow muscle, or forcing apparatus, which, in glancing at the differences of structure, we have spoken of as the *heart* superadded to the circle of vessels, which even in its simplest state consists of at least two cavities communicating with one another, one for the reception of the blood from, the other for the projection of this fluid to the general system.

But the blood does not follow the direct and simple course here supposed in almost any case. There is the aeration of the fluid in the way, and means to accomplish this important end must of course be provided. Among many animals it would appear by no means necessary that the *whole* of the blood should undergo exposure in the respiratory apparatus, in order to fit it for the wants of the organization; a *part* only is sent thither, and this on admixture with the remainder suffices to revivify the mass. In this case it is not imperative that the two kinds of blood—the unaerated or venous, and the aerated or arterial—should be kept distinct; there is consequently no occasion for more than one recipient cavity or auricle, into which the aerated blood from the organ of respiration, and the unaerated blood of the system are poured in common and mingled, and one projecting cavity or ventricle from which the mixed current is distributed partly to the respiratory apparatus and partly to the system at large. Here the blood in its course describes no more than a single circle, beginning and ending in the heart, which is then characterized as *simple*, consisting, as has been said, of a single auricle and a single ventricle. Among other tribes of animals, however, the whole mass of blood requires to undergo aeration in the respiratory apparatus each time it completes its round before it can again subserve the wants of the organization. In this instance it is evident that the aerated and unaerated blood require to be most particularly prevented from commingling, and that a single or simple heart will no longer suffice as the implement of circulation. This complex circulation is met with among animals so low in the scale as to be unprovided with a heart, when of course it is accomplished by means of vessels only. In some tribes the one portion of the function is performed by the medium of vessels, the other by the agency of a heart which is now connected with the general systemic circulation, now with the pulmonic, being situated in the one case in the course of the aerated, in the other in that of the unaerated current of blood. In the most elevated classes of animals, finally, the double circulation is effected by means of *two* hearts, one dedicated to the projection of the unaerated blood into the lungs, the other to the propulsion of the aerated fluid through the general system. These two hearts, indeed, adhere to one another, and are usually spoken of as if they constituted no more than a single organ, having however four cavities, two auricles and two ventricles, but they are not less distinct on that account, and are severally the centre of a particular circulatory system, one of which commencing in the cavities for the venous or unaerated blood, extends through the respiratory apparatus (then uniformly a lung), and back to the cavities for the arterial aerated blood; the other, commencing in the cavities just named, extends to every part of the organization, and terminates in the cavities for the unaerated blood, where the lesser round recommences, to be followed in its turn by the greater, and so on, during the whole period of existence.

Assimilation appears to be identical in all animals; it is the ultimate term of nutrition, and however varied the apparatus that ministers to the act, the act itself we may presume not to differ in its essence in one animal from what it is in another.

Akin to assimilation we have *secretion*, and this is a function that offers extensive differences in every class of the animal kingdom. It is generally spoken of as of two kinds, *excretion*, and *secretion*, properly so called. In the lowest tribes excretion is quite simple, consisting of a mere exhalation from the general surface of the body. In the more elevated we find another and very important form of excretion superadded, that, namely, of the urine, the nature of which, and the mode in which it takes place, we have already indicated in speaking of the structure. Secretion, however, even in the classes but a little raised above the lowest, is a function of much more varied import, and consists of a great many other processes than that by which the bodies of animals are depurated and their blood maintained in a state fit to supply all the wants of the system. We advance but a little way before we begin to detect distinct organs destined for the secretion of peculiar fluids from the general mass of circulating nutriment, evidently subservient in many cases to the most important ends of the economy, and by no means destined to be rejected from the system as useless, like the excretions properly so called. It seems even that it is by a process analogous to secretion that the imponderable matters—the heat, light, and electricity, which we have acknowledged as elements in the constitution of organized beings, are eliminated.

All animals possess *sensibility* or *sensation*, though evidently in the most dissimilar degrees. Some have been supposed to possess the faculty of perceiving impressions made upon them by external objects, but to have no power of reacting upon external nature, they being without the faculties which in the higher classes prompt to action. This state, however, of animal existence is rather hypothetical than demonstrable, and in animals generally we observe not only the aptitude to be impressed, but inherent capacities inducing reaction upon the world around them. The sensitive life of these beings consequently consists of two items—the senses and their organs, external and internal, by which impressions are received and cognized, and the affective and intellectual faculties by which the motives to action, the propensities, sentiments, instincts, appetites, &c., are originated, and the means and modes of accomplishing their promptings are supplied.

Animals evidently differ immensely in the degrees in which they are endowed with external and internal senses. Some appear to possess none of the external senses save touch; others, in addition to this, have taste and smell; the most perfect besides these three reckon sight and hearing. The internal senses, in like manner, are more or less acute, more or less numerous, according to the consitution of animals: those of hunger and thirst are probably universally distributed, and the most keenly felt; then come those which induce the respiratory act, the sexual act, &c.; and here we find ourselves among the *propensities* which exist in very different numbers and kinds in every different species of animal. Some tribes tend their offspring, others leave their progeny to the care of accident, which in this case always suffices for their protection; some congregate in herds or shoals, others live solitary or in pairs; some are bold and rapacious, others timid and gentle, &c. When we examine animals generally, with reference to the sentiments or *moral faculties*, we find them still more or less like each other in many respects, some being cautious or cowardly, proud or haughty, persevering or obstinate, &c., in various proportions. When we contrast all other animals with man, however, in regard to moral endowment, we immediately perceive the broad, the impassable line of difference that runs between the lord of creation and all the other beings that with him partake of life. The feeling which leads man to view his actions in their bearing upon others or in relation to justice, is extremely weak among animals, if indeed it do actually exist among them at all. The same may be said of the sentiment which leads mankind to wish well to all, and to succour and relieve those that are suffering and unfortunate. The feeling, again, that raises man to the imagination of a something beyond nature, the sentiment that inclines him to reverence and adore his Maker, thus in one way revealed to him, and the wonderful impulse that leads him to look beyond time and his merely temporary existence, and thence to conceive infinity and eternity, are so many moral attributes which man alone, of all created things, possesses.

Similar diversities in intellectual endowment are apparent when we survey the animal kingdom at large. Intelligence appears utterly wanting in numerous and extensive classes, and it varies conspicuously in the members of every tribe among which it is apparent. In his intellectual powers man is not less eminently raised above all the other beings of creation than in his moral constitution: he alone takes note of the phenomena that pass around him with ulterior views, and he alone perceives the relation between effect and cause, preparing and foreseeing consequences long before they happen.

Locomotion is a function so evidently in relation with the circumstances surrounded by which animals exist, and with the apparatus by which it is accomplished, that it is enough to refer back to the structure for proof and illustration of its infinite modifications among the various genera and species of the animal kingdom. Some, by their constitution, are incapable of motion from place to place, but they still perform those partial motions which their preservation as individuals require—taking their food, respiring, voiding their excretions, &c. Those that can move from one place to another have organs in relation to the mode in which this motion is accomplished, whether it be by creeping, by swimming, by running, leaping, flying, &c. &c. Every partial movement executed by the higher animals has, farther, its own special apparatus: the intestinal canal has its muscular parietes; the necessity that is felt to communicate internal sensations and ideas has its pathognomonic means in the looks, gestures, sounds of the voice, and so on.

Nor is it only in the greater or less degree of complexity of their general structure, in the number and diversity of their particular organs, or in those of the actions whose sum constitutes their vitality, that animals differ from one another; they vary farther in the degree in which these organs and these functions are enchained or mutually dependent. In the most simple animals so complete is the independence of the several parts, that their bodies may be divided into numerous pieces without injury to the vitality of any one of them, each possessing in itself the capacity to commence a separate existence. In animals somewhat more elevated in the scale we observe very extensive powers of reproduction at least, of parts that have been lost, and even of continuing existence in very insignificant remainders of their bodies. In the most elevated tribes, however, the dependence of every part upon the whole becomes such that neither will the body essentially mutilated survive, nor will any part of the slightest consequence continue to live. Among the beings at the bottom of the scale we have in fact found the organization to be homogeneous, or without distinction of parts, and nutrition to be accomplished by means of an immediate absorption and exhalation; and as every part possesses the structure which makes it capable of these two acts, every part, it is evident, suffices for its own existence. In the higher classes of animal existence, however, nutrition requires the concurrence of a multitude of peculiar acts; and in order that life may be continued in any fragment of one of the members of these, it is plain that this fragment must contain the organs of every one of the functions essential to nutrition. Further, it is certain that the nervous system, when once it has fairly made its appearance, strictly dominates the nutritive function, and that every part of the nervous system itself becomes progressively more and more dependent on one of its portions, the encephalon or brain, as animals stand higher in the scale of creation, and as the functions over which the nervous parts preside respectively are themselves of a higher order. These are new and additional reasons for the centralization of life, or for the complete dependence of the organs and their functions one upon another among the more perfect animals—man, the quadrumans and quadrupeds, birds, &c.

So much for the acts that minister to the preservation of the individual. Let us now turn to the interesting series by which species are continued. In the very lowest grades this end is accomplished without the concurrence of sexes: at a determinate period of its life the animal either separates into several fragments, which become so many new and independent individuals, or it throws out a number of buds or germs from its external surface or from a particular internal cavity. The first of these modes of reproduction is entitled *fissiparous*, the second *external gemmiparous*, and the third *internal gemmiparous*.

When we examine animals in the next grade, we find reproduction taking place by the concurrence of sexes, or rather of two kinds of organs which we afterwards discover divided between different individuals, who are then said to be of opposite *sexes*. When the male and female organs are united in the same individual it is denominated an *hermaphrodite* animal, and in some cases seems to suffice for its own impregnation; more generally, however, hermaphrodite animals are not capable of performing this act upon themselves, but require the concurrence of another individual of similar constitution: the two hermaphrodites meet and severally impregnate one another.

Among the more perfect classes of the animal kingdom the organs of reproduction are universally allotted to two different individuals, *males* and *females*, which consequently become in their dualism representatives of their species. Agreeing in this single feature, the modifications in the process of reproduction are nevertheless extremely numerous. In some cases the fecundating fluid of the male is only applied to the egg or germ of the female after its extrusion from her body, as happens among fishes, several reptiles, &c.; in others the male fluid is injected into the body of the female, and made to fecundate the germ still attached to its parent. This act is generally, though not invariably, accomplished by means of a *penis*, or male external organ, with which many birds and all the animals above them in the scale of animal creation are then provided.

With this contact or intermixture of bodies we have the following varieties in the after-parts of the process: the egg or germ now fecundated is either forthwith expelled from the body, and it is only subsequently, under the influence of a certain temperature, and after the lapse of a certain time, that the young being bursts the shell and commences its independent existence; this is the case among *oviparous* animals. Or otherwise: the fecundated egg makes its way so slowly through the passages that lead from the ovary outwards, that it is hatched before it can escape, so that the young one passes from the body of the mother immediately. Animals in whom this happens are justly said to be *ovo-viviparous.* In the third and last place, the fecundated ovum is immediately loosened from the ovary, but instead of being laid, or extruded from the body immediately, it only passes along a canal to a certain distance from the ovary, where it meets with a reservoir or cavity (the uterus) to which it attaches itself, and within which it commences a series of evolutions, at the expense of the mother, preliminary to its final expulsion with instincts ready formed, and an organization so perfect as enables it to begin its separate existence. The classes in which this mode of reproduction obtains, and they are the highest of all, including quadrupeds and man, are entitled *viviparous,* so that in these, besides the connection of the sexes and the fecundation of the germ, we have the phenomena of utero-gestation and labour.

And here the proper work of reproduction ends; but the young are so generally born in some sort immature, that in the higher classes the connection between the offspring and parent does not cease immediately. In the class of mammalia, indeed, the connection is little less intimate during the earlier periods of extra uterine life than it was during the whole term of intra-uterine existence; the young being still depends upon its mother for the whole of its nourishment, and very generally for the supply of warmth it requires and the protection needful to it till able to provide for itself.

Many of the particulars now merely glanced at, and numerous others, the mention of which has been omitted entirely, will be found detailed, and their bearing and importance illustrated in the article on Generation, to which the reader is therefore referred.

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(R. Willis.)

ANKLE, REGION OF THE, (surgical anatomy), (*region tibio-tarsienne*, Velp.) The relative positions and other particulars connected with the parts found in the region of the ankle, owing to the numerous accidents which occur here, are matters of great interest to the surgeon. The extent and boundaries of this region are by no means so distinctly defined as those of many others; hence, in isolating it for special description, the surgical anatomist is obliged to assign to it arbitrary or imaginary limits. We propose to adopt the following boundaries for this region, viz. superiorly a horizontal line drawn round the leg two inches above the malleoli, and inferiorly a line drawn across the dorsum and sides of the foot at the same distance from those bony prominences. In this space are comprised the ankle-joint and several important vessels, tendons, and other soft parts well worthy of attention.

In examining the external characters of this region we notice four well-marked prominences, one on either side, termed *malleolus*, (*internus* v. *externus*); a third posteriorly, which corresponds to the tendo Achillis; and a fourth in front, resulting from the projection of the astragalus. The malleoli do not accurately correspond either in situation or shape to each other: the internal lies upon a plane superior and anterior to the external, and in a well formed person is much less sharp and prominent,—a fact, the recollection of which is of great importance in estimating deformity or dislocation of the joint. The cylindrical prominence behind, as it depends upon the tendo Achillis, will of course vary in size and tension according to the relaxation or contraction of the gastrocnemii muscles. Upon either side of the tendo Achillis, between it and the malleolus we meet with a deep groove, called by some the calceo-malleolar furrow: that upon the outside is extremely well marked, and we may here distinctly feel through the integuments two of the peronei tendons: the internal calceo-malleolar groove is broader and shallower, but of much greater interest, for through it, in addition to certain tendons, we have transmitted the principal vessels and nerves destined for the sole of the foot. The anterior prominence, named in popular language, "the instep," is rounded in the transverse direction, and in some individuals projects much more than in others. On throwing the foot and toes into action, as in walking, we can here distinctly recognize the tendons of the tibialis anticus, extensor pollicis, extensor digitorum longus, and peroneus tertius, and almost in the mesial line may be felt pulsating distinctly the anterior tibial artery.

Having thus examined the landmarks which are to guide us in our anatomical investigation of this region, we may next proceed to inquire into the nature and relations of its constituent parts. Besides the bones, cartilages, and ligaments which immediately constitute the joint, and form the basis of the region, we have likewise several other structures entering into its formation; integuments, muscles, vessels, nerves, and fasciæ are here arranged in successive layers beneath each other. We shall accordingly describe four layers,—namely, 1. the skin; 2. the subcutaneous cellular tissue; 3. the fasciæ; and 4. the tendons, vessels, and nerves, which lie in immediate contact with the articulation.

1. *The skin* forms a complete investment for the whole region, but its structure and properties differ considerably in different situations. Upon the inner ankle it is smooth and thin, and possessed of but little extensibility; so that in operating here, if we look forward to union by the first intention, it becomes a matter of great moment to preserve as much

of the skin as possible. Owing to the same peculiarities of the integuments in this situation, no less perhaps than to the frequent motion of the part, wounds and ulcers occurring upon the inner ankle are extremely tedious and troublesome, in many instances laying bare the bone, and finally even occasioning its destruction. Upon the outer ankle, the skin is more pliant and extensible; hence the greater facility of healing wounds and ulcers in this part; and hence, too, the more frequent occurrence of abscess and extravasation beneath the surface. At the posterior part of the region the skin acquires great strength and thickness, becoming as it passes downwards still more dense and unyielding, approximating in fact to the character of the plantar integument. Upon the instep it is also of tolerable thickness, particularly in those individuals whose feet are usually uncovered. In this situation, however, it is soft and extensible: its natural pliancy being still further increased by the secretion of numerous sebaceous follicles thickly scattered throughout its substance. It is here, owing to the frequent motions of the joint, thrown into transverse rugæ, and hence, in making an incision, to give exit to matter, it may be proper to prefer a transverse to a vertical direction.

2. *The subcutaneous cellular tissue.*—The structure and properties of the subcutaneous cellular tissue are not the same throughout the whole region, but like the skin, which we have just considered, its characters vary in different situations. Thus, upon the instep, it is at the upper part loose and distensible, full of adipose cells, and similar in every respect to the subcutaneous tissue of the leg, of which it is a prolongation: as it descends, however, it becomes more dense and unyielding, and adheres more closely to the skin which covers, and to the annular ligament which is placed beneath it. This anatomical fact at once explains why it is that when subcutaneous abscess or infiltration occurs on the anterior part of the leg or foot, the passage of the fluid either upwards or downwards is, for a time at least, impeded at the ankle-joint. It is likewise owing to the density of the subcutaneous tissue across the ankle, that its cells do not permit the accumulation of adipose substance here; hence in very fat persons and also in children whose subcutaneous fat is usually abundant upon the leg and foot, the instep is as it were strangulated by a deep transverse furrow. Upon the malleoli the characters of the subcutaneous tissue present great differences: upon the inner one it is scanty and delicate, but of a compact structure, and contains few if any adipose cells. Upon the outer one it is, on the contrary, much more copious, of a loose and yielding texture, and usually contains a greater quantity of fat. These differences of texture will explain why, after severe contusion, extravasations so frequently occur upon the outer part of the joint and so seldom upon the inner; why abscess is so much oftener met with in the one situation than in the other; and why the transmission of pus and serum from any of the neighbouring regions takes place so much more easily about the outer than about the inner ankle. At the posterior part of the region, the subcutaneous tissue assumes again new characters: losing here its soft lamellated texture it becomes suddenly dense and filamentous, adhering with great firmness to the integuments above, and to the fascia beneath: as we trace it down it becomes more dense and elastic; the cells formed by the decussation of its filaments become loaded with a firm granular fat; in a word, it already begins to put on the characters of the dense fibro-adipose cushion, which is found in the sole of the foot. Hence it is that wounds and abscesses of the part we are now considering, approach in character those of the plantar region: hence the slight swelling, the severe pain; hence in both cases the necessity of a prompt and free evacuation of the matter.

Before leaving this subject we should observe that the subcutaneous tissue of the region we are now considering transmits certain vessels and nerves. In front of the inner ankle we meet with the incipient branches of the great saphena vein and the ultimate filaments of the saphenus nerve: the venous branches are here of such a size that they have frequently been selected by the phlebotomist as the seat of operation. Anteriorly we find the filaments of the musculo-cutaneous nerve, and externally the roots of the lesser saphena vein, and its accompanying nervous filaments.

3. *The fascia* or *aponeurosis* forms the next stratum we have to examine: it is placed between the subcutaneous tissue and the tendons. The fascia, like the two preceding layers, forms a general investment for the whole region. Its structure and properties, like those of the preceding layers, vary considerably, according to the situation in which we view it. Upon the instep it becomes continuous, above with the aponeurosis of the leg, and inferiorly with the dorsal aponeurosis of the foot, but, for very obvious reasons, surpassing both of these in strength. This additional strength is owing to the accessory band of fibres which passes transversely across the instep, interlaced with the proper oblique fibres of the fascia, and to which is given the name of *anterior annular ligament*. Arising from the anterior edge of the inner ankle this annular ligament passes outwards and soon meets with the tendon of the tibialis anticus: at this point it splits into two layers; the one passes before, the other behind the tendon, and they unite again at its outer edge. The same mechanism is repeated in the case of the extensor pollicis tendon which lies immediately external to the last-named tendon; and lastly in those of the extensor digitorum longus and peroneus tertius. In contemplating the mechanism and uses of this ligament, the surgical anatomist cannot but perceive that certain inconveniences must result from its division: its use being obviously to bind down the tendons in this situation, and to form canals for their free and separate transmission, it is clear that after its division in the

living subject, when the individual attempts to flex the foot or extend the toes, these tendons will not only form an unseemly projection upon the instep, but also the accuracy and perfection of these motions will be much impaired. Upon the lateral parts of the region, the fascia is so intimately united to the periosteum, that it is almost impossible to separate them from each other, and hence some have denied its existence here. Behind both malleoli, it becomes however again very distinct, forming in both situations a band similar to that which we have just seen upon the instep. The *internal annular ligament* arising from the posterior edge of the inner malleolus passes backwards to the os calcis; it is thrown like a bridge across that deep gutter which divides the heel and ankle from each other, and it is destined like the anterior ligament to form a covering to the tendons and other parts which pass through this region. Like the anterior, the internal ligament also consists of two layers closely united to each other. To express more distinctly the mechanical disposition of these layers, we may say that the bridge formed by the internal annular ligament consists of two arches; through the anterior arch are transmitted the tibialis posticus and the flexor digitorum longus tendons, wrapped each in its own synovial theca: the posterior arch is occupied with the posterior tibial vessels and nerves, and the tendon of the flexor longus pollicis muscle. Having thus safely conducted these important organs, the superficial layer of the ligament fixes itself into the os calcis, while the deep one passes backwards and upwards to become continuous with the deep fascia of the leg. Behind the external malleolus, the fascia forms another but less remarkable ligament, which Blandin calls the "external annular:" this passes from the fibula to the astragalus, and forms with the posterior edge of the malleolus a deep osseo-fibrous canal for the transmission of the peroneus longus and brevis tendons.

At the back part of this region, the fascia is also found covering the great tendo Achillis; this tendon also, like the smaller ones we have just spoken of, is not merely covered superficially, but is contained within a sheath, formed by the splitting of the fascia into two layers: the posterior layer we may regard as the continued fascia itself; the deep one passes in front of the tendon, and if we trace this upwards, we shall find it becoming ultimately continuous with the deep fascia of the leg. An acquaintance with the disposition and structure of the fascia we have thus described, will enable the surgical anatomist, in almost every instance, to explain the time, situation, and progress of abscesses occurring in this region: he will at once comprehend that three distinct sorts of abscess may form here:—one in the subcutaneous tissue, and which being superficial to the fascia can hardly penetrate deeply toward the joint; another, occurring between the two layers of that membrane, in those situations where it splits to include the tendons; such an abscess will have little tendency to point in front, being bound down by the superficial layer of the fascia, or to penetrate deeply for a similar reason; but to its free passage upwards or downwards in the course of the tendons, little or no obstacle is presented. Lastly, matter may accumulate under both layers of the fascia, where its deep position and close confinement render it alike dangerous, and of difficult detection.

4. The next stratum is perhaps less entitled to that name than those we have hitherto described. Instead of forming, like them, a general investment for the whole region, it consists of several distinct and independent organs scattered irregularly about the joint: we shall enumerate them in the order in which we propose to treat of them, viz., tendons, muscles, arteries, veins, lymphatics, and nerves.

a. *Tendons.* Upon the instep we find no fewer than seven tendons passing towards the foot: the internal is the largest of all, it is that of the tibialis anticus running obliquely forwards and inwards to the inner cuneiform bone. Close upon its outer side is the tendon of the extensor pollicis; still more outwards we meet with the four tendons of the extensor digitorum longus, and most externally of all, or nearest to the outer ankle, that of the peroneus tertius. We need not revert to the subject of the fibrous sheaths furnished to these tendons by the fascia or annular ligament; but we should here carefully observe, that both sheaths and tendons are completely lined by a synovial apparatus. He who is at all acquainted with the general pathology of synovial membrane will understand why it is that effusions so frequently form about the instep; why adhesion of the opposite walls of these synovial sheaths will almost destroy the power of extending the toes and of flexing the foot; and, lastly, he cannot but draw the important practical deduction, that in operations about the instep we should avoid, if possible, cutting into these synovial sacs.

Behind the inner malleolus we meet with three tendons, — that of the tibialis posticus most anterior, and in close connexion with the posterior surface of the malleolus internus; that of the flexor digitorum longus a little further back; and still more posterior, and at a little distance from the others, the tendon of the flexor pollicis longus. These are included, as we have already explained, in fibrous sheaths formed by the internal annular ligament, each sheath and tendon having its own synovial lining. We may here observe a good anatomical reason, why inflammation affecting the sheath of the flexor digitorum will, *cæteris paribus*, be more likely to prove dangerous than that of the tibialis posticus: for, as the synovial sheaths of the former extend along the whole sole of the foot, little or no obstacle is presented to the disease extending itself into that region: whereas the tendon of the tibialis being inserted, not upon the sole, but rather upon the inner edge of the foot, its synovial membrane forms here a cul-de-sac, no doubt presenting some obstacle to the inflammation extending beyond this point. Behind the outer malleolus there exists a deep groove, in which two important tendons are contained, those, namely, of the peroneus longus and brevis. They are lodged in a canal which we have already described as formed by the bone and the external annular ligament, and this canal is lined by a distinct synovial membrane reflected upon it from the tendons. Having passed over the ligaments of the outer ankle, the peronei tendons are next applied upon the surface of the os calcis; and here, though previously in close apposition, and indeed contained within the same synovial sheath, they become separated by a ridge projecting from the bone. The peroneus longus tendon plays behind it as upon a pulley, and instances have occurred, where, owing to the fracture of this little osseous septum, the peroneus longus has been dislocated forwards upon that of the brevis. It has also happened that both peronei tendons have been dislocated forwards from their groove behind the malleolus, and thrown in front of that eminence. Were such an accident left without surgical interference, it is interesting to reflect how completely altered would be the action of these two muscles, if that action were not completely suspended by the inflammation and obliteration of the synovial sheath consequent on the accident; instead of extending the foot and pointing the toe, as they do in their natural state, they would become converted into flexors and abductors of the foot. At the posterior part of the region, the tendo Achillis forms a remarkable projection. In our account of the fascia, we have described the sheath within which this tendon is contained. We may further observe that this tendon is separated from the joint, and also from the deep vessels and nerves of the leg, by a considerable interval, so that it has frequently been cut across without injury to the articulation or wound of any other important part. Its mode of insertion into the os calcis is also worthy attention; instead of being fixed into the whole posterior surface of that bone, it occupies by its insertion merely the lower half of it; superiorly the bone and tendon are not even in contact, for here a distinct synovial bursa is interposed between them. The liability of this large bursa to inflammation and effusion should be carefully borne in mind by the surgeon: and he who is aware of its office, placed as a friction roller between the tendon and bone, will duly estimate how much disease of this bursa will impede the motions of progression. Owing to the interposition of the bursa, rupture of the tendo Achillis has occurred even below the upper edge of the os calcis; and if, having cut across the tendon, we forcibly extend the foot so as to elevate the heel, we shall at once comprehend how indispensably necessary it is to maintain the extended position in our treatment of this important accident.

b. *Muscles.*—There are but few muscular fibres met with in the region of the ankle: the flexor digitorum brevis arises upon the instep; and posteriorly we find some of the fibres of the flexor pollicis longus, which are here continued down a considerable way upon the tendon.

c. *Arteries.*—The arteries about the ankle, from their liability to injury and disease, become of great interest. Upon the instep the course and relations of the *anterior tibial* artery demand particular attention; the vessel here does not run exactly in the median line of the foot, but is somewhat nearer to the inner than to the outer malleolus: we may always reach it with perfect certainty, by cutting between the tendon of the extensor digitorum longus, and that of the extensor pollicis; these overlap it upon either side, and afford considerable protection against wounds or other injuries. Notwithstanding the facility of reaching the vessel in this situation, it is by no means advisable to do so when it is at all possible to avoid it, inasmuch as to expose the artery here it is necessary to wound the synovial sheaths, and inflammation and adhesion would be the probable consequence of such an injury. The branches of the *internal malleolar* artery are found upon the inner part of the region, running upon and in front of the inner ankle, and anastomosing with others passing forwards from the posterior tibial, thus insuring a sufficient supply of blood to the joint, even when the trunk of the anterior tibial itself has been tied. But these vessels are of much inferior importance compared with the posterior tibial, whose main trunk lies in the fossa between the heel and the malleolus internus. It is here occasionally the subject of operation, and hence its course and relations should be very carefully noted. We have already enumerated the tendons passing beneath the annular ligament in this situation; the most anterior is that of the tibialis posticus, immediately behind it lies that of the flexor digitorum, and still more posteriorly, at the interval of about an inch, is found the tendon of the flexor pollicis; in this interval between the two latter tendons runs the posterior tibial artery, not however equidistant from both, but nearer to that of the flexor digitorum; it rests upon the tibia and internal tibio-tarsal ligament, and is covered by the integuments and annular ligament; its venæ comites run one upon either side; and the posterior tibial nerve lies close behind it, but as the vessel descends getting gradually to its inner side. Notwithstanding the few coverings of the artery in this situation, yet owing to the heel, the ankle, and the tendo Achillis projecting around, and bearing off as it were those coverings from it, the vessel is here at a considerable depth from the surface; and any one who supposes it can be easily found in the living subject, will form a very erroneous idea of its true position:—hence it is that all good writers on surgical anatomy recommend us to take up the artery in the lower third of the leg, rather than in the calceo-malleolar groove. Several small vessels ramify about the outer ankle, the external malleolar coming from before meets here with the terminating branches of the peroneal artery from behind, but these small vessels are interesting to the surgical pathologist rather than to the regional anatomist or operative surgeon.

d. *Veins.*—Two veins, the "venæ comites," accompany each of the larger arteries: in all operations upon the artery, the close apposition of the veins, and the possibility of mistaking one for the other, should be remembered by the surgeon. In front of the inner malleolus we observe one or two openings in the fascia, through which small branches of communication pass between the superficial and deep veins; these, no doubt, are the principal channels through which the venous blood of the integuments about the foot and instep is returned, after the operation of tying the great saphena vein.

e. *Lymphatics.*—The lymphatics consist likewise of two sets; the one lying beneath the integuments and scattered irregularly over the region; the other lying beneath the fascia, and for the most part accompanying the blood-vessels. Some anatomists speak of a lymphatic gland lying upon the instep, and receiving several of these deep absorbents; in the majority of cases there is no such gland, and its existence in any appears to us extremely doubtful.

f. *Nerves.*—The nerves in this region have the same general distribution as the arteries. In our account of the larger arteries, we have already minutely assigned the relation which their accompanying nerves bear to them. We may thus briefly enumerate them:—in front, the musculo-cutaneous and anterior tibial; on the inner side the terminal ramifications of the internal saphenus and the posterior tibial; and on the outside, the terminal branches of the external saphenus. For further particulars respecting the nerves, we refer to the articles LUMBAR NERVES; SACRAL NERVES.

For the BIBLIOGRAPHY of this article and all others on surgical anatomy, see the Bibliography of ANATOMY (INTRODUCTION.)

(*John E. Brenan.*)

ANKLE, JOINT OF THE.—(Normal anatomy.) (Fr. *articulation du coude-pied.* Germ. *Fussgelenk.* Ital. *caviglia.*) The ankle-joint, or tibio-tarsal articulation, results from the junction of the leg and foot. For reasons which will appear when we come to explain its motions, it is ranked in the excellent and comprehensive classifications of Bichat and Cloquet as a perfect angular ginglymus. The security of the ankle-joint, more perhaps than of any other in tbe body, is owing to the peculiar form of its bones, and to their exact adaptation to each other; in this respect it has aptly been compared to the *tenon* and *mortise* joint, so frequently used by mechanics, the strength of which, as is well known, is chiefly owing to the peculiar form and close fitting of its component parts. Upon the upper part of the foot, we meet with, it is said, a true and well defined tenon, and upon the lower part of the leg a tolerably perfect mortise for the reception of the tenon. The comparison, though perhaps not strictly correct, will however assist us in understanding how much the security of this joint depends upon the form and fitting of its bones; and will explain to the beginner why, in treating of the ankle-joint in particular with a view to demonstrate its use and mechanism, a brief account of its bones becomes part of our description no less essential than of its ligaments themselves. In our account, therefore, of this articulation, we shall, in the first place, describe its bones; next its ligaments; and, lastly, shall offer some remarks upon its mechanism and uses.

a. *The Bones.*—Three bones contribute to the formation of the ankle-joint; the tibia and fibula form, by the union of their inferior portions, a deep depression, into which the head of the astragalus is received. The *tibia*, as it approaches the joint, looses gradually its prismatic shape, and assumes a well-defined cubical or quadrangular form. On its lower extremity it presents a quadrilateral articulating cavity, covered in the recent state with cartilage; this cavity is transversed from before backwards by an obtuse ridge which subdivides it into two smaller cavities. Of the four sides or margins of this articulating cavity, the anterior is almost straight transversely, but convex or rounded off in the vertical direction, with the obvious design of permitting a greater flexion to the foot; the anterior tibio-tarsal ligament arises from this margin. The posterior margin is also straight transversely, but vertically convex, to permit an increased extension to the foot; the posterior tibio-fibular ligament is connected here: a shallow oblique groove is met with upon the outer part of this surface, for the transmission of the flexor longus pollicis tendon. The external side presents a depression for the reception of the fibula; this articulating portion is prolonged upwards for nearly an inch, is of a triangular form with the base below; the sides of the triangle give attachment to the anterior and posterior tibio-fibular ligaments; and the area of the triangle is rendered rough, except at its lowest part, by the attachment of the inferior interosseous ligament,—another strong bond of union between tbese bones. The inner edge is prolonged downwards nearly an inch in length, forming the prominence known by the name of *malleolus internus;* this is placed upon a plane superior and anterior to the malleolus externus; it is somewhat flattened in shape, and has one surface looking inwards or towards the mesial line; this in the living subject is covered only by the integuments; the outer surface enters into the formation of the joint, hence it is tipped with cartilage to permit the astragalus to play upon it; the anterior edge is sharp and gives origin to the anterior tibio-tarsal ligament; the posterior edge is traversed by a broad and generally well-marked groove, which transmits the tendons of the tibialis posticus and flexor digitorum longus; the apex of the malleolus is below, and gives attachment to the deltoid or internal tibio-tarsal ligament.

The *fibula*, as it approaches the foot, becomes suddenly enlarged in size, applies itself firmly to the tibia, and then descends nearly an inch and a half below its point of union with that bone. The prominence formed by the fibula in this situation is named the *malleolus externus;* it is much larger than the internal, and placed behind and somewhat below it. The external surface of this fibular malleolus is covered merely by the integuments; the internal surface is tipped with cartilage, and convex in the vertical direction, being received upon a corresponding concavity on the outer side of the astragalus; upon the lower and back part of this inner surface may be seen a deep depression, where the posterior fibulo-tarsal ligament arises; the anterior edge of the malleolus is sharp, and gives origin to the anterior fibulo-tarsal ligament; the posterior edge is marked by a deep groove, which transmits the tendons of the peronei muscles, longus and brevis. The apex of the malleolus is below, and gives origin to the middle fibulo-tarsal ligament.

The *astragalus* enters into the formation of the ankle-joint by its superior surface, and a portion of its two lateral surfaces. On the superior surface we observe, anteriorly, a well marked groove forming part of the neck of the astragalus; into this groove the anterior tibio-tarsal ligament is inserted. Immediately behind the groove we meet with an articulating eminence of an oblong quadrilateral form, an inch and a half in its antero-posterior, and about an inch and a quarter in its transverse measurement; (this transverse measurement is, however, a little greater in front than behind;) the eminence is remarkably convex from before backwards, and concave from side to side; the outer edge somewhat more elevated than the inner; it is completely covered with cartilage, and corresponds to the articulating cavity upon the inferior exremity of the tibia. Upon the inner side of the astragalus, we find a small articulating surface of a triangular form, with the base above and apex below; it is convex in the vertical direction, and is tipped with cartilage prolonged ftom the superior surface: upon the triangular surface the internal malleolus plays; the remaining portion of the inner side of the astragalus is rough, and occupied chiefly by the insertion of the internal tibio-tarsal ligament. The external side of the astragalus is also marked by an articulating surface of a much greater size for the reception of the external malleolus: it too is of a triangular form with the base above; concave iu the vertical, and slightly convex in the antero-posterior direction.

b. *Ligaments.*—We have already compared the mechanism of this joint to that of the tenon and mortise; the mortise cavity, however, is not, as we have seen, cut out of a solid bone, but being formed in great part in the lower extremity of the tibia, is completed on the outer side by the fibula, which is firmly united with the tibia by strong ligaments, formiug what is called the *inferior tibio-fibular* articulation. We shall not now describe the ligaments which here unite the tibia and fibula, referring to the article on the Tibio-fibular Articulation; but we must observe that, however it may be advisable, in anatomical descriptions, to separate this last named articulation from the ankle-joint, they are perfectly inseparable in their functions, the integrity of the latter being essentially dependent on that of the former: indeed it may be said, that, by virtue of the great strength of the ligamentous connexion between the tibia and fibula in the former articulation, the mortise is as strong, nay, in some respects stronger, than if it had been formed out of solid bone.

The ligaments which connect the tenon and mortise together, or to speak more literally, which tie the tibia and fibula with the tarsus, are five in number, namely, two tibio-tarsal and three fibulo-tarsal ligaments.

1. The *internal tibio-tarsal ligament* is also called the *internal lateral,* and by Weitbrecht the *deltoid* ligament. There is, however, no reason why we should not apply to it likewise that principle of nomenclature which is so generally and with such advantage applied to other ligaments. It arises by a truncated apex from the point of the inner malleolus, and from the little fossa at its outer surface; its fibres change as they proceed downwards and are fixed into the inner surface of the astragalus and os calcis, some proceeding as far forwards even as the scaphoid bone. The posterior fibres are strong but short; the anterior are much larger and not so thick. Its internal surface is lined by the synovial membrane of the joint; and on its internal surface it is covered by the tendon of the tibialis posticus, and it sends some of its fibres to the sheath of the flexor longus digitorum tendon. In flexion of the leg the anterior fibres are relaxed, and the posterior are rendered tense: in extension the reverse of course takes place. 2. The *anterior tibio-tarsal* ligament *(lig. tibio-tarsal,* Cloquet) consists of a few loose fibres scattered over the synovial membrane, and in some instances so delicate and so separated by pellicles of fat as to be scarcely perceptible. They arise from the fore part of the inner malleolus and the adjacent anterior portion of the tibia, and descend obliquely downwards and outwards to be inserted into the neck of the astragalus. This ligament is covered anteriorly by the tendons of the tibialis anticus, extensor proprius pollicis, and extensor digitorum longus: posteriorly it is in contact with the synovial membrane. 3. The *anterior fibulo-tarsal* ligament *(lig. fibulæ anterius,* Weitb., *anterior external lateral,* Boyer) arises from the anterior edge of the outer malleolus, a few lines from its extremity; it descends obliquely forwards and inwards, and is fixed into the astragalus immediately in front of the articulating surface which receives the fibula: it is scarcely an inch in length, of an oblong quadrilateral form, and is frequently subdivided into two distinct parts. In extension of the foot it is rendered tense; in flexion it is relaxed. 4. The *middle fibulo-tarsal* ligament *(lig. fibulæ medium perpendiculare,* Weitb., *external lateral ligament,* Cloq.) is a round fasciculus of fibres having almost the appearance of a tendon which arises from the apex of the external malleolus, descends obliquely backwards, and is attached to the outside of the os calcis. It does not appear to us that in any position of the joint this ligament takes a perpendicular course, although that epithet has been applied to it by Weitbrecht. It is related superficially to the peroneus longus tendon, and by its deep surface to the synovial membrane, to the astragalus, and os calcis. In flexion of the foot this

ligament is rendered tense; hence it appears designed to limit motion in this direction: in extension it is of course relaxed. 5. The *posterior fibulo-tarsal* ligament (*lig. fibulæ posterius*, Weitb., *posterior external lateral*, Boyer) arises from the little fossa upon the inner and back part of the outer malleolus; it passes backwards and inwards almost horizontally, or at least descends very slightly, and is inserted upon the back part of the astragalus into the outer edge of that groove which transmits the flexor longus pollicis tendon. This ligament is stronger than either of the two preceding, and is frequently divided into several distinct fasciculi. From its superior edge an accessory band sometimes passes upwards and inwards over the synovial capsule to be fixed into the tibia. Walther has described this band under the name of the oblique ligament, and it is well represented by Weitbrecht (*fig.* 65, tab. xxii.)

The *synovial membrane* of the ankle-joint is of very great extent: it lines not only the articular surface of each malleolus, the several ligaments we have just described, and the articulating cavity upon the lower portion of the tibia, but it is prolonged upwards between the tibia and fibula, forming in that situation a little cul-de-sac: this, however, is merely for the extent of a few lines, for its further progress upwards is interrupted by the inferior interosseous ligament, (*fig.* 61.) From the circumference of the tibio-fibular mortise the synovial membrane passes downwards upon the astragalus, covers its superior articulating eminence, and sends prolongations upon its lateral articulating surfaces. It is remarkably loose upon the anterior and posterior parts of the joint, and is said to contain a greater quantity of synovia than any other synovial membrane in the body. Certainly its strength is much increased by those scattered fibres to which we have given the name of anterior tibio-tarsal ligament: posteriorly it is weakest, for here few if any ligamentous fibres can be detected, though Boyer and Weitbrecht speak confidently of such.

c. *Mechanism and function of the ankle-joint.*—To understand properly the mechanism and function of the ankle-joint, we must carefully contemplate it in the opposite conditions of rest and motion.

1. Viewing it, then, in the first place, as the individual stands at rest, we observe that the leg and foot meet each other in the ankle-joint at a right angle, and we are particularly struck with this fact upon finding that this disposition occurs in scarcely any other animal than man. This interesting fact in comparative anatomy is by no means an accidental arrangement; its design is obviously in reference to the proper position of the body in each animal. It has, for instance, frequently been alluded to as one of the many anatomical proofs that the erect position is natural to the human subject: had the leg and foot been articulated at any other than a right angle the upright position of the body could not be maintained, at least without great and incessant muscular exertion. Another point worthy of our attention is that when the ankle is at rest and the body in the upright position, the fibula plays no part in the function performed by the joint: it is the tibia alone which receives the weight of the body, and transmits it to the astragalus. This fact should be carefully borne in mind, for it has considerable influence upon the accidents so frequently occurring here. The astragalus, from the way in which it supports the body, has often been compared to the key-stone of an arch, the arch being represented by the foot. That the foot presents an arched concavity at its lower part cannot be doubted; but it is by no means so certain that this is designed upon the principle of the architectural arch to support the weight of the body: in fact, the astragalus, which receives the entire weight, does not correspond to the centre of this arch. The true design of the vaulted form of the foot is to permit its accommodating itself to the several irregularities of surface which, both in standing and progression, it must encounter.

The motions of flexion and extension are the only ones permitted at the ankle-joint. In *flexion* the astragalus rolls from before backwards in the tibio-fibular mortise; it may be continued until the foot and leg form with each other an angle of about sixty degrees; at this point further flexion is prevented, partly by the tension of the middle fibulo-tarsal ligament, and still more effectually by the neck of the astragalus coming into contact with the lower edge of the tibia. In flexion the anterior tibio-tarsal and fibulo-tarsal ligaments are both relaxed; the posterior and middle fibulo-tarsal are rendered tense; the internal tibio-tarsal ligament has its posterior fibres stretched and its anterior ones loosened. 2. In *extension* the foot not only returns to its rectangular position with the leg, but may even be carried beyond this, so as to form with the tibia an obtuse angle of about one hundred and fifty degrees.* Further extension is at this point prevented by the tension of the ligaments which lie in front, and also by the astragalus behind coming into contact with the lower edge of the tibia. During extension the astragalus rotates forwards in the tibio-fibular mortise; the posterior ligaments are relaxed, the anterior are put upon the stretch, the state of each individual ligament is, in short, reversed from what we have just described as its condition in the opposite motion of the joint. 3. A slight degree of *lateral motion* of the ankle is perceptible in the dead subject, but during life it cannot be said to exist: hence, in the classification of Cloquet and Bichat, the joint is properly ranked under that variety of ginglymus to which we apply the term "perfect."

The ankle is the analogue of the wrist-joint in the superior extremity, and accordingly, though there are certain points of difference between them, the general character of both is

* According to Hildebrandt the angle of flexion is 45°, and the angle of extension according to Rosenthal (Handb. der Chir. Anat.) is 175°.—Ed.

the same. It is no less interesting than instructive to contrast these two articulations with each other, for in doing so we find that the modifications of structure here, as well as in all other instances, are referable to the peculiar function which each part is destined to perform. The hand in the human subject is exclusively an organ of prehension; the foot is one merely of support:—now this simple fact at once furnishes us with a clue to all difficulties. The great strength and sudden expansion of the tibia and fibula at the ankle, are evidently a provision to sustain the weight of the body and to increase the basis of its support; in the radius and ulna such size and strength would have been to no purpose, and hence these bones at the wrist are comparatively thin and delicate. At the ankle we should naturally have expected frequent dislocations, owing to the great weight from above, and to the great mobility which for the purposes of progression must at the same time necessarily exist here; these are two most formidable causes of displacement; but, as if in compensation, we find two strong buttresses (the malleoli) projecting one upon either side of the joint, and rendering such displacement, under ordinary circumstances, almost impossible. At the wrist, where there is no weight to be supported, such lateral splints would have been superfluous: hence the imperfect and almost rudimental malleoli of the radius and ulna; hence the shallow and imperfect cavity; hence, in a word, the anatomical conformation which constitutes the ankle-joint a ginglymus, and the wrist an arthrodia. In the motions of the ankle and wrist-joints we observe likewise a striking difference: in the former, lateral motion would have been superflous in reference to the function of the foot; at the wrist, on the contrary, a free lateral motion is indispensable to increase the sphere of action of the hand.

For the BIBLIOGRAPHY of this article, see that of ARTICULATION.

(John E. Brenan.)

ANKLE-JOINT, ABNORMAL CONDITION OF THE.—The deviations from the natural or normal condition of the ankle-joint may be classed under those which are referable to accident and to disease: any defects which may be considered to result from congenital malformation shall be elsewere treated of. (See FOOT.)

Accidents.—The different structures which immediately compose the ankle-joint, as well as those which surround this articulation, and are merely accessary to its functions, are, each and all, liable to numerous accidents, the most important of which we shall here advert to.

These accidents may affect the *tendons*, the *ligaments*, or the *bones*.

Tendons.—Those tendons which pass behind the inner and outer malleoli are occasionally displaced; and, although the accident must be considered a rare one, it ought not here be overlooked.

"The two peronæi extensor muscles," says the late Mr. Wilson,* "where they pass behind and below the fibula over a smooth lubricated surface of that bone, are bound to it by a strong ligament; but should the ligament give way, one or both of these tendons may escape from the groove or pulley in which they usually play, and being thrown forwards over the edge of the bone, in this new situation their action on the foot will be to bend it on the leg, when in their natural position it was to extend it. The peronæi having been habituated to act with the extensor muscles, continue to contract at the same time with them, but now they oppose the effect which formerly in conjunction with the extensor muscles they produced upon the foot, and by so doing excite much pain and irritation in addition to the lameness. When this situation of the tendon is discovered early, the tendon can be readily restored to its proper place, but if this is not done, it forms a new groove on the fore part of the bone, and the old one is filled up, or otherwise so altered that it cannot receive the tendon, and thus the pain and lameness may continue for life. I have seen this occurrence sometimes in the living body early enough to return the tendon, and have been consulted in cases where it could not be returned; in one, where the pain was so violent that I recommended the division and removal of part of the tendon; the muscle then contracted to its full extent, and afterwards shrunk, and no inconvenience was felt after the operation. I have met with two or three instances of this kind of displacement of tendons in bodies brought into the dissecting-room; but of the previous history of the cases I could know nothing." Mr. Wilson adds, "Those tendons which pass in grooves behind the inner ankle are liable to a similar displacement." Of the latter accident we have known but one instance, but of the former several.

Ligaments. — Accurate anatomical investigations of the actual condition of the various structures which compose the ankle-joint, when affected by a sprain, have shown that in slight cases of sprain of this joint nothing unnatural has been discovered, as the bonds of union between the bones have been merely stretched or strained. In others more severe, the ligaments have been found broken or torn from their attachment to the bones, the synovial sac opened, and its fluid to have escaped from the cavity of the joint; the cellular tissue around has been filled with extravasated blood, and with synovial and serous fluids. In these cases the nerves, bloodvessels, tendons, even the skin itself, have been subjected to a degree of stretching and extension, more or less considerable. Baron Dupuytren, from numerous observations on the living subject, from post-mortem examinations, and experiments, is of opinion that a slight accidental torsion of the foot inwards or outwards, amounting to a sprain, only produces an injury, in which

* Wilson's Lectures on the Bones, &c.

the ligaments are merely stretched; but that a greater effort produces a separation of the lateral ligament from one or other of the malleoli by laceration of its compact tissue, or of the periosteum which covers it, while the ligaments themselves remain unbroken. Opportunities do not often occur of discovering the effects of sprains on the joints by anatomical examination made at various periods after the accident; but although Dupuytren's opinion may be correct as to the majority of cases, still others have found the lateral ligaments ruptured across, instead of having been torn from the bone. Mr. Wilson found, in a case where the patient died five days after a severe sprain of the ankle-joint, that the deltoid ligament binding the tibia to the foot was lacerated, and that the synovial membrane of the ankle-joint was also much torn. In older cases he found evidences of chronic inflammation in the ligamentous structures around the joint; that these structures were thickened and vascular, and had lost much of their pliability.

The pain and inability to walk, the sudden effusion around the injured ankle, the ecchymosis, tenderness of the skin and tension, the signs of this injury expressed by the living structures, are all accounted for by the lesions which an anatomical examination of these injuries of the ankle-joint discovers. This also explains what practical writers have noted of sprains, viz. that sometimes the ankle-joint which has been affected by this accident, rapidly and perfectly recovers,—that, on the other hand, it is not unfrequently so weakened by the injury, as to become peculiarly susceptible of a renewal of the sprain from slight causes; sometimes the articulation contracts a rigidity, by which for a time, or even for life itself, its proper functions are interfered with, and a permanent œdema of the soft parts around the joint is too often in these cases established.

Bones. — The bones which contribute to form the ankle-joint are liable to fracture and to luxation. These bones, we know, are the tibia, fibula, and astragalus; for an account of the accidents which affect the latter particularly, we refer to the article Foot, and shall here, as succinctly as we can, notice the various displacements of the bones of the leg at the ankle-joint, which have been observed to be the result of a fracture through one or both of the malleoli, or of an accidental rupture of the ligaments which tie these eminences to the foot.

When we reflect on the great strength of the ligaments which connect the astragalus to the tibia and fibula, and the support which the articulation derives from the prolongation downwards of the malleoli, we can easily perceive that a luxation of the foot must be the effect only of some very violent cause, and that this accident can very rarely (in a true sense) be a simple one. Effusions of blood, rupture of all the surrounding ligaments, fracture of the external or even of both the malleoli, wounds of the soft parts, and even protrusion of the bones, are contingences which frequently render the dislocation of the tibia at the ankle-joint a very complex accident.

The most superficial view of the structure of the ankle-joint will convince any one that no lateral displacement of the bones of the leg can occur, without its having been immediately preceded by a fracture of either the tibial or peronæal malleolus; but such a view would warrant the conjecture, that a luxation in the direction forwards or backwards may possibly take place, simply from the rupture of the ligaments of the joint alone, and the action of muscles. Such a luxation as this last, when no fracture exists, should be best entitled to the name of simple; yet those luxations of this articulation (such is the vagueness of surgical language), whether accompanied with fracture or not, are all called simple, provided there be no wound through the integuments communicating with the cavity of the joint. In this latter case alone the luxation is denominated compound, of which it is not our intention here to treat.

We shall arrange the luxations of the bones of the leg at the ankle-joint in the above sense called simple luxations, into those which occur in the direction *inwards*, *outwards*, *forwards*, and *backwards*, and each of these, it is believed, may be a partial or a complete luxation.

Luxation of the Tibia inwards.—This luxation may be complete or incomplete: we shall first treat of the most common form of it or that termed partial Dislocation of the Tibia inwards from the Astragalus, or Pott's luxation. Mr. Pott, in describing this accident, observes, "that the support of the body, and the due and proper use and execution of the office of the joint of the ankle, depend almost entirely on the perpendicular bearing of the tibia upon the astragalus, and on its firm connexion with the fibula. If the former bone is forced from its just and perpendicular position on the astragalus; or, if it be separated by violence from its connexion with the latter, the joint of the ankle will suffer a partial luxation internally: this is the case when, by leaping or jumping, the fibula breaks in its weak part, within two or three inches of its lower extremity. When this happens, the inferior fractured end of the fibula falls inwards towards the tibia, that extremity of the bone which forms the outer ankle is turned somewhat outwards and upwards, and the tibia, having lost its proper support, and not being of itself capable of steadily preserving its true perpendicular bearing, is forced off from the astragalus, inwards, by which the ligaments are torn, thus producing a perfect fracture and a partial dislocation."*

If we are called to examine a patient who has recently suffered this accident, we find that the ankle-joint now possesses some degree of lateral mobility. In the normal state of the ankle-joint we know that the quadrilateral cavity formed by the tibia and fibula for the

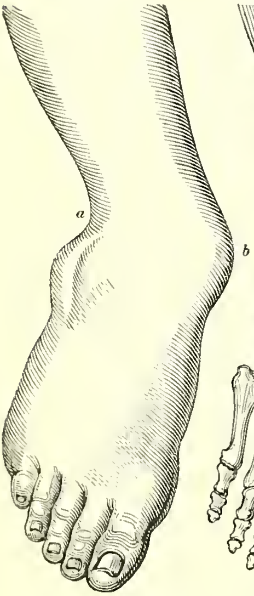
* Pott's Works by Earle, vol. i. p. 327.

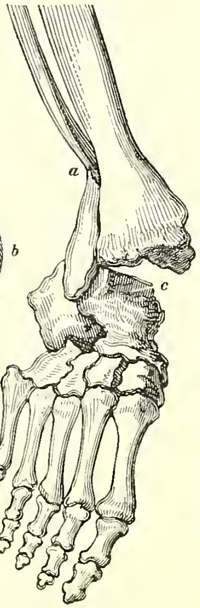
reception of the astragalus, makes with the latter a perfect mortise joint, which admits of motions of flexion and extension, but allows of no motion whatever laterally or horizontally; for it must be recollected that those motions of inclination of the foot, known under the names of adduction and abduction, are not movements in the ankle-joint, but take place in the joints of the tarsus: but the unnatural mobility in question is very great when the fibula is broken at its lower part; this is shewn, when, after the surgeon has bent the limb to relax the muscles, the leg is fixed by one hand placed at its lower extremity, whilst the other moves the foot from within outwards; the foot is then seen to move in a transverse line and to quit the axis of the leg; the malleolus internus projects inwards, and the malleolus externus is moved upwards and outwards, and all these appearances vanish, when by a contrary movement we bring the foot to its natural position.

When we leave the limb for a moment to itself, we notice that there is a remarkable change in the point of incidence of the axis of the leg upon the foot. The tibia and upper fragment of the fibula, although really remaining in their natural position, *appear* driven inwards, while the foot is rotated outwards.

The changes of direction of the leg and foot are such, that if the axis of the leg were prolonged inferiorly, instead of falling on the astragalus, it would leave this bone, and consequently the whole foot, more or less on its outer side; hence the impossibility patients experience of bearing upon the foot, which only presents its inner edge to the ground.

Fig. 51. *Fig.* 52.





Partial luxation of the Tibia inwards, or Pott's luxation.

This change is a necessary and constant effect of the displacement of the foot, when the fibula ceases to support it on the outer side, and when the peronæi muscles begin to contract. The foot and external malleolus which make part of one system, move in one direction; the tibia and upper fragment of the fibula move, or, to speak perhaps more correctly, remain, in another. The centre of this new motion is no longer in the articulation, but, in an oblique line, passing through the joint, and extending from the malleolus internus to the point of fracture of the fibula: this line is well expressed in *fig.* 51, representing the fracture of the fibula, and taken from the engraving which accompanies the work of Pott.

The retiring angle seen *(fig.* 51, 52, *a)* in this partial luxation of the tibia inwards, on the outer part of the articulation, and the projecting one *(b)* existing at the inner, constitute the most striking features of the accident; these angles correspond exactly to the extremities of the line above-mentioned, in the direction of which the weight of the body aets, when the foot being turned outwards this line may be seen to traverse the leg obliquely from the lower part of the upper fragment of the broken fibula to the malleolus internus.

We cannot omit to notice also, that there is in all these cases a remarkable rotation of the whole foot on its long axis, in such a direction that the upper surface of the astragalus looks obliquely upwards and inwards, *(fig.* 52, *c,)* the inner edge of the foot is turned downwards, the sole inclined outwards, the outer edge raised, and the dorsum turned directly upwards. The extent of this rotatory motion is besides always proportioned to the displacement outwards; both are attributable to the same causes, viz. the weight of the body, and the action of the peronæi muscles, when the patient has attempted to walk after the fracture has occurred.

It is on these combined movements when not corrected by a proper mode of treatment, that the deformity of the foot, and all the consequent difficulties in walking, depend.

Complete luxation of the tibia inwards from the astragalus, complicated with a simple fracture of the fibula.—This is a very severe, and, fortunately, a very rare accident. In alluding to it, Dupuytren says,* that "the foot is not only susceptible of being carried outwards, but also upwards at the same time;" a double displacement, which he had observed to occur only once in 200 cases of fractures of the fibula treated in the Hôtel Dieu for fifteen years, "but the case was so marked," he says, "that in future it cannot be mistaken or passed over in silence." It cannot occur unless the fibula is fractured; for this condition is indispensable to any displacement of the foot inwards or outwards; it requires besides a complete laceration of the short thick ligaments placed between the tibia and fibula, the strength of which is such that, in most experiments on

* Sur la Fract. de l'Extremité inferieure du Peroné, in Annuaire Med. Chir. des Hopitaux de Paris, 1809, 4to. and folio.

the dead subject, they resist more powerfully than the structure of the bones themselves.

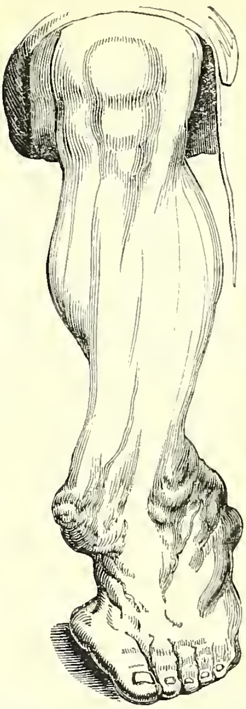
It was as a consequence of the fracture of the fibula and a rupture of these ligaments, that, in the case alluded to, the astragalus was seen dislocated outwards, and then drawn up on the outer side of the tibia. In short, the astragalus, the malleolus externus, and the foot, which formed but one system of parts firmly connected, were drawn first to the outer side of the leg, and then two inches upwards on the tibia.

A carpenter, aged fifty-four years, was admitted into the Hôtel Dieu, in February, 1816. His right leg presented all the signs of fracture of the fibula at its inferior part, such as deviation and rotation of the foot outwards, prominence of the tibia, and of the internal malleolus inwards, depression and crepitation above the outer ankle; but that which most attracted the attention was, 1st, the shortening of the limb, and, 2dly, the enormous increase in breadth of the space which should naturally intervene between the two malleoli. The sinking down of the lowest part of the tibia, even to the level of the sole of the foot, where the projection of the internal malleolus could be felt, the elevation of the astragalus, of the peroneal malleolus, and the whole of the foot along the external surface of the tibia, even to two inches, were all symptoms quite unusual in fracture of the fibula, and left no doubt that the ligaments which stretched inferiorly from this bone to the tibia had been lacerated, and that the foot, yielding to a violent effort from within outwards, and from below upwards, had been luxated in these directions, and had carried with it the peroneal malleolus. This then is evidently a case of complete dislocation of the tibia inwards, or, as the French writers would call it, a luxation of the foot outwards and upwards.

Although this species of luxation has not been specially described in any of our English works, I doubt not but such an accident has been observed, although it is possible that its nature was not always clearly understood. Sir A. Cooper, in his valuable work on Dislocations and Fractures, states that the foot has also been known to be thrown upwards, between the tibia and fibula, by the giving way of the ligament which unites these bones; but he adds that this accident is only an aggravated form of an internal dislocation.

We find but little difficulty in comprehending how the accident described by Dupuytren may occur, because, the fibula having been first fractured, the broken bone and ruptured ligaments permit the foot to yield to the powerful action of the muscles on the back part and outside of the leg, which draw it at first outwards, and then upwards; but on the contrary, it is not easy to imagine any force capable of overcoming the resistance of the many inter-osseous ligaments which exist, and of the fasciæ and annular membranes which surround the bones of the leg: a force must be great indeed which can overcome the muscles also, and cause a divarication of the bones of the leg sufficient to permit the astragalus and rest

Fig. 53.



Complete luxation of the tibia inwards or of the foot outwards and upwards.—(Dupuytren.)

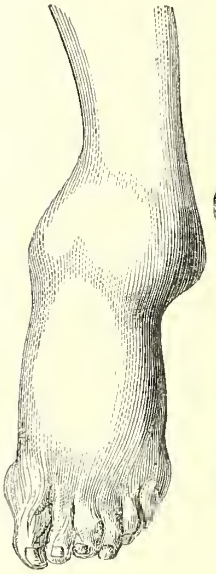
Fig. 54.

Dissection of a case of the same class as fig. 53, *from the museum of St. Thomas's Hospital.*

of the foot to be thrown upwards between the tibia and fibula. Supposing this last case possible, the shortening of the limb and its newly-acquired breadth between the malleoli might lead to error, and the two cases here alluded to be at first sight confounded; but in Dupuytren's case, the fracture of the fibula, the overlapping of its fragments, and above all the ascent of the external malleolus, so much above the level of the internal, will always constitute such characteristic marks, that when such an accident presents itself, we conceive it cannot be confounded with any other injury of this articulation.

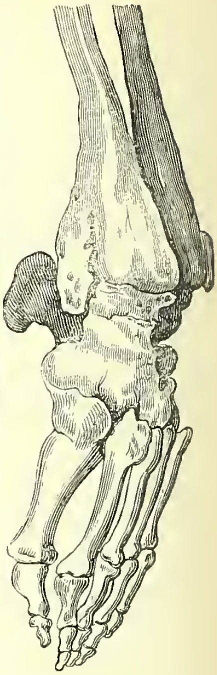
What are the anatomical characters of this complete luxation of the tibia inwards, with displacement of the foot and outer malleolus upwards and outwards? It is evident that there must be very extensive injury done in such cases to the ligaments and bones; the fibula must be fractured near the ankle, and it is probable that some fragments of the tibia may be carried off with the fibula, for such is the strength of the ligaments between the lower part of the tibia and fibula, where these unite for the reception of the astragalus (*vid. fig.* 61), that there is reason to believe that the bone itself would break before the ligaments would yield. If a portion of the tibia, however, is not broken off and carried with the fibula, these transverse fibrous bands must be torn, as well as those oblique ligaments which pass before and behind from the fibula to the tibia. The proper interosseous membrane itself must be detached from between the bones to allow the astragalus to ascend along the outside of the tibia. While the ligaments which connect the outer malleolus to the tibia must be torn, those which unite it to the foot remain entire, the deltoid or internal lateral ligament must be completely torn across, as well as the synovial sac of the articulation; nor should it be forgotten that the annular ligaments and strong fasciæ at the lower part of the leg, must, in so severe and extensive an injury, be lacerated; the tendons, muscles, and other structures may escape injury, the astragalus and outer malleolus are dragged up (*fig.* 54, *a*, *b*), their ascent being only limited by the lower point of the upper fragment of the fibula (*c*), which remains in its natural relation to the tibia, except that it must be somewhat approximated to it; the lowest point of the superior fragment of the broken fibula rest upon the summit of the articular pulley of the astragalus, as is well seen in a preparation preserved in the collection of St. Thomas's Hospital Museum, the delineation of which we have borrowed from Sir A. Cooper's work. The preservation of this specimen, which in our mind is a true example of the complete dislocation of the tibia inwards, and of the external malleolus astragalus and foot upwards and outwards, is a new proof of the truth of the observation we have above made, that this severe accident had not altogether escaped the notice of English surgeons, although the "*Annuaire*" contains the first accurate account of the external signs by which it may be recognized in the living subject.

Fig. 55.



Luxation outwards of the tibia and fibula with oblique fracture of the tibia.

Fig. 56.



Dissection of the luxation outwards (Museum of St. Thomas's Hospital). [*Fig.* 55.]

Luxation of the tibia outwards, complicated with simple fracture of one or both of the malleoli.—This, it is said, is one of the most dangerous of the dislocations to which the ankle is liable, for its production has been noticed to be attended with greater violence, and to be accompanied by more contusion of the integuments, more laceration of ligaments, and greater injury to bone, than we have occasion to observe in the production of the other luxations of this joint.

The astragalus in this accident is carried towards and below the external malleolus (*fig.* 55), whilst the outer edge of the foot is turned downwards, its inner edge upwards, and the sole inwards, the tibial malleolus disappears, and is hidden at the bottom of a retiring angle formed by the inner side of the leg and foot, and the peroneal malleolus forms, with the astragalus, a salient angle rounded off on the outside. Looking only to the change of form, situation, and relative position of the leg and foot, we might suppose the case one of congenital club-foot.* The luxation of the tibia outwards, with inversion of the sole of the foot, is one of the most rare and most difficult cases to explain. Its production must be the result, we suppose, of coincidences rare and unusual. There may be a certain obliquity in the line of direction of the fracture coinciding with a considerable degree of resistance in the lower fragment of the fibula: thus, if we can suppose that a fracture shall traverse the tibia obliquely from above downwards, and from within outwards, so that the point of the upper fragment be directed downwards and outwards, and the lower fragment point upwards and inwards, and if to this obliquity we suppose added a certain resistance on the side of the lower fragment of the fibula, it is plain that the foot being unable to turn outwards, must be carried inwards by the action of the muscles, and with this inversion, &c. some little shortening of the limb, at least when measured on its inner side, may be expected.

If this accident be neglected, the cure which nature attempts is very imperfect, the ankle-joint becomes stiff and rigid (*fig.* 56), the interval between the internal and external malleolus is much increased, the latter presses heavily against the integuments, which, when the limb is much exercised, have a strong tendency to inflame and suppurate, the outer edge of the foot throughout its whole line presses the ground, whether the patient be standing or walking, while the inner edge is somewhat elevated and curved inwards. In the dissection of this accident, it will be found that the

* Dupuytren, Annuaire.

malleolus internus is fractured, and in general, we suppose, with the obliquity from above downwards, and within outwards, above described. The deltoid ligament remains unbroken, the capsular membrane is torn in front, the fibula has been found obliquely fractured, as well as the tibia, or the three ligaments which connect it to the tarsus have given way; none of the tendons suffer, and hæmorrhage to any extent in these cases seldom or never occurs, as the large arteries generally escape injury.

Luxation of the tibia and fibula forwards, and also luxation of these bones backwards from the articular pulley of the astragalus, without fracture.—In the simple and complete luxation of the bones of the leg forwards at the ankle-joint, (without fracture,) the articular pulley of the astragalus is placed behind the inferior extremity of the tibia, which last rests partly on the superior surface of the neck of the astragalus, and partly on the os naviculare.

In the simple and complete luxation of the tibia backwards, (without fracture,) the inferior extremity of the tibia is placed behind the articular pulley of the astragalus, and corresponds to the posterior part of the superior surface of the os calcis. In both these luxations, the natural connexion with each other of the bones of the leg remains undisturbed, and the two malleoli advance or recede together, according to the direction in which the displacement has occurred. In both, the capsular membrane and the posterior and lateral ligaments must be extensively lacerated, and most of the flexor and extensor tendons, in some degree, put upon the stretch.

The luxation of the bones of the leg forwards cannot take place, but in a forced and sudden extension of the leg on the foot, when the latter being retained by some obstacle, and solidly supported, we fall backwards.

The luxation of the tibia backwards, on the contrary, cannot happen unless when the foot is strongly flexed, the toes being elevated and retained in this position, we fall forwards.

Authors have seldom failed to notice these simple luxations forwards and backwards of the bones of the leg, yet for our part, no matter to what source we apply for information, we cannot satisfy our minds that we can adduce a single well-marked example of luxation of the bones of the leg at the ankle-joint, *unaccompanied by a fracture of one or both of the malleoli;* we would not, however, be understood to deny the possibility of such an occurrence, but merely to state our conviction that such an accident must be exceedingly rare.

We have now to consider luxations of the tibia from the astragalus, forwards and backwards, when complicated with a simple fracture of the fibula or tibia close to the articulation: these may be complete or partial.

Complete luxation of the tibia forwards from the articular part of the astragalus complicated with a simple fracture of the fibula.—This accident may arise from the same causes nearly as those which may be supposed to influence the more simple luxation in the same direction; and as we know that when the fibula is fractured near its malleolus, the peronæi muscles may under certain circumstances effect a luxation of the tibia inwards, so that displacement which we are now considering may be the result of the action of the gastrocnemius and solæus. These acting on the foot, which in consequence of the fracture is no longer fixed by the malleolus externus, cause the astragalus to slip from before backwards, and the lower end of the tibia forwards, and move the lower fragment of the fibula in such a manner that its malleolar extremity is carried backwards, and the upper part forwards. This action of these muscles, however, only produces a very incomplete dislocation whenever the internal malleolus is uninjured, or the foot in this case being carried outwards and backwards at the same time; but when, as often happens, either the internal malleolus or deltoid ligament is broken, this displacement may be as complete and direct as the simple dislocation forwards of the tibia. We then find the foot lengthened behind and shortened in front; a semicircular excavation occurs in the former direction, and an osseous tumour raises the tendons and ligaments on the front of the ankle, but it is to be particularly remarked that, whilst in the simplest form of luxation of the tibia, i. e. where there is no fracture, the external malleolus follows the tibia and fibula, and forms a projection corresponding to that of the internal, it is in this case dragged backwards with the foot to which it is attached by the lateral ligaments, and no longer has the same direction as the bones of the leg.

In the dislocation forwards of the tibia (whether simple or complicated with a fracture of the fibula) from the astragalus, the articular pulley of this bone is placed behind the inferior articular cavity formed for it in the tibia; but this latter bone at the same time, it will be recollected, must now rest on the dorsum of the tarsus, where it is formed by the upper part of the neck of the astragalus and os naviculare. When the tibia has thus once advanced before the articular pulley of the astragalus, the luxation forwards is as complete as it well can be; in our opinion, to imagine any more complete luxation of the tibia forwards, we should be obliged to presume that this bone in its advance on the dorsum of the foot had completely cleared the astragalus, and then rested "on the *os naviculare and os cuneiforme internum*,"* which last form part of the anterior

* The weight that so justly attaches to any observations from Sir A. Cooper, induced us to consider well the account he gives of the dissection of this complete luxation of the tibia forwards, in his work on Dislocations and Fractures; and we find that we cannot reconcile it with our ideas of the anatomy of the injury. We are sorry in this instance to be obliged to differ from an authority, to which we feel indebted for many observations copied into these pages; but we think there must be error in the following passage taken from the valuable work to which we allude, page 178, 8th edition.

"On dissection, the tibia is found to rest upon the upper surface of the os naviculare and os cuneirange of the tarsus, a situation which the tibia could not well occupy, without a previous lesion of the tendons of the tibialis anticus, and stretching of the other extensors: from such a relative position of the bones of the leg and foot would result a shortening of the dorsum of the foot and an elongation of the heel to an extent which, we believe, has never been noticed.

Partial luxation of the tibia forwards, with simple fracture of one or both of the malleoli.—The complete luxation forwards of the tibia from the astragalus, which we have described in the preceding section, all writers look upon as the more common form of dislocation forwards; while the partial luxation in this direction is considered a rare accident. My opinion upon this subject is quite different; for some experience in these accidents leads me to say, that a complete luxation of the tibia forwards from the articular pulley of the astragalus is rare, but that a partial luxation in this direction accompanied with a simple fracture of one or both of the malleoli, is an accident by no means uncommon.

The signs of this partial luxation of the tibia forwards are nearly the same as those we have stated to belong to the complete luxation in this direction; they are, however, as might be expected, more faintly marked, and, consequently, may more easily be neglected; but, after all, these signs are so evident, that it is wonderful how with common attention they can be overlooked. It may not be amiss to subjoin the following case as illustrative of the common partial luxation forwards:—

A man, aged twenty-two years, was admitted into Jervis-Street Hospital, at three o'clock, A.M. of the 26th of December, 1833. He stated that he and a *friend* had been drinking together in a public house, that in the middle of the night they quarrelled, that he was knocked down, and was unable to rise, in consequence of his having received a severe injury of his left ankle: his friend then procured some assistance and carried him to the hospital; at my visit, I found him in bed, complaining of much pain, his leg extended and resting on its outer side; the heel was retracted, and between it and the calf of the leg, instead of the ordinary line which marks the course of the tendo Achillis, there was a conspicuous semicircular curve, (*fig.* 57, *a*, *b*); in a word, the heel was lengthened, and the dorsum of the foot seemed much shortened; in the situation of the ankle-joint in front, there was a remarkably hard, prominent, transverse ridge made by the advance of the lower extremity of the tibia and extensor muscles of the toes, while beneath this there was a marked depression, where the skin and annular ligament seemed, as it were, pinched in, drawn under the lower edge of the articular part of the tibia; the foot was pointed downwards, no movement of flexion or extension could be communicated to the ankle-joint, but it admitted of some little motion in a horizontal, and also in a lateral, direction, when the leg was firmly grasped with one hand and the foot moved with the other.

It was remarkable that, although the man had no power whatever over the motions of the joint, he could, while he lay in bed, move his whole limb about with much freedom, and (as there was probably a locking of the bones with each other) these voluntary movements were not accompanied by any increase of pain.

The fibula could be felt to be fractured about an inch and a half above the lowest point of the outer malleolus, "the foot, the outer malleolus, and short portion of the broken fibula, formed one system of parts," and were carried for the length of an inch or more horizontally backwards, while there was a projection forwards, of the lower articular part of the tibia, and the internal malleolus itself was advanced in the same proportion: it is to be observed, that there was no crepitus, because it was the deltoid ligament only which was torn; the tibia was not broken, and the ends of the fractured fibula were evidently far separated from each other. When the luxation was reduced, which was effected without much difficulty, crepitus could be felt, proving the restoration to its place of the lower fragment of the fibula.

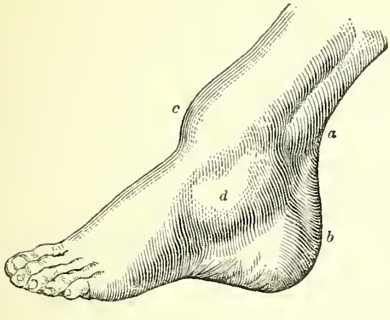
This is a species of fracture and luxation, which can, by proper management, be readily redressed, and no deformity remains, if time be not lost after the accident has occurred; but if the fibula become solidly united in its new situation, the motions of the ankle-joint are for ever lost, and the patient is doomed to lameness for life.

In the month of September 1833, a woman, aged fifty-three years, was admitted into Jervis-street Hospital, whose left ankle-joint presented all the characters above assigned to the partial dislocation forwards of the tibia, combined with a simple fracture of the fibula; she stated that she had, two months previously, broken her leg close to the ankle joint, and had been attended at her own house, from a dispensary, by a pupil, who applied pads and lateral splints, but when after a time all the splints were removed, she found that her limb was deformed, her ankle stiff, her foot rigidly extended, and pointed downwards, so as to be nearly useless to her; as two months had elapsed since the accident, before she applied, no promise of relief could be held out to her. She therefore left the hospital, but not before I was enabled, through the kindness of Mr. Sutton, to obtain a cast of the leg and foot, from which figures 57 and 58 are copied. As I

forme internum, quitting all the articulatory surface of the astragalus, excepting a small portion on its fore part, against which the tibia is applied." Now, a single glance at the skeleton of a foot will shew us, that a portion, however small, of the articulatory surface of the astragalus, together with, secondly, the upper part of the neck of this bone; thirdly, the os naviculare; and, fourthly, the os cuneiforme internum, nearly form a space equivalent to a third of the length of the whole foot, an extent of surface, which, manifestly, the articulating portion of the dislocated tibia could not occupy.

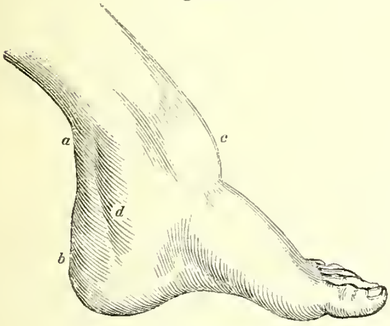
Partial luxation forwards of the tibia at the external ankle, with fracture of the fibula near the malleolus.

Fig. 57.



Viewed on the external side.

Fig. 58.

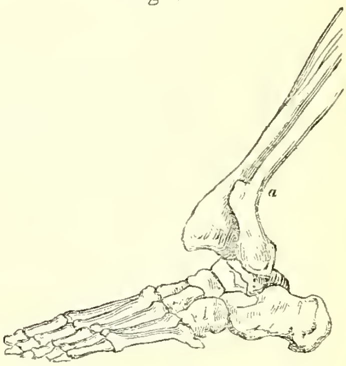


Viewed on the internal side.

a, b, semicircular excavation posteriorly, and projection of the heel backwards; *c* prominence formed by the tibia projected on the dorsum of the foot; *d* displacement of the external malleolus backwards along with the foot.

was anxious, before these pages went to press, again to examine this case, I requested Mr. S. to make inquiry about her; he learned that the woman died dropsical a few days before, and with much difficulty procured for me an opportunity to examine the limb, which on careful dissection presented the following appearances:—the whole extremity was somewhat wasted, the skin on the sole of the foot was smooth and fine, shewing that she had been able to walk but little since the accident; the foot was in a position of almost rigid extension, the toes were directed downwards, the range of motion of flexion and extension did not exceed one inch, in short, all the usual characters assigned to the partial dislocation forwards of the tibia and displacement of the foot backwards were seen; when the skin was removed from the fascia of the leg and foot, the intervening cellular membrane was found infiltrated with serum, the skin was adherent to the inner malleolus, the vena sapbena and the nerve of the same name were thickened and firmly connected together, the extensor tendons were stretched over the tibia, and were somewhat flattened, and the grooves which transmit the tendons that play behind the inner and outer malleolus were deepened. We now directed our attention to the state of the bones; we found that the tibia was displaced forwards, that its anterior edge was advanced more than one inch beyond its natural situation, and that it much overhung the os naviculare, but such was the direction and state of obliquity of the tibia with respect to the foot, that it could not be said to rest upon that bone; between the os naviculare and the inferior articular extremity of the tibia there intervened much fat of a yellow hue and fibrous texture, like intervertebral substance; the internal malleolus itself had not escaped injury, the deltoid ligament had not in this instance as in the former given way; the internal malleolus itself had been broken, and a small portion of the back part of the edge of the articular cavity of the tibia was detached, and both malleoli were retracted, or carried backwards with the foot; the fibula above the fractured portion was directed downwards and a little forwards, and was somewhat parallel to the tibia, yet more tban naturally approximated to it, a circumstance which accounted for the contracted rounded form the middle of the leg possessed; the lower frag-

Fig. 59.



Viewed on the external side.

Fig. 60.

Viewed on the internal side.

Skeleton preparations of fig. 57 *and* 58.

ment of the fibula was directed from below upwards, a little inwards, and very much forwards, so as to make with its shaft a remarkable angle salient anteriorly; this bone had been traversed by the fracture obliquely, from above downwards and from before backwards. The external malleolus was placed about one inch and a quarter behind its usual situation, and was consequently dislocated at its tibio-fibular articulation, having burst those strong ligaments which connect these bones together, and which are so seldom found to yield.

Luxation of the bones of the leg backwards at the ankle-joint.—A luxation of one or both bones of the leg at the ankle-joint backwards, whether the accident be what has been called complete or incomplete, whether accompanied with a fracture of the fibula, or merely with a rupture of the ligaments, is a displacement which must be considered exceedingly rare. Boyer, in his valuable work, gives no case of it from his own observation; and in alluding to such an accident, states that no author, to his knowledge, has given a single example of it. Sir A. Cooper evidently has not seen it; for he says, " I have seen the tibia dislocated in three different directions, inwards, forwards, and outwards; and a fourth species of dislocation is said sometimes to occur, viz. backwards." Baron Dupuytren states that he has never seen this accident.*

Mr. Colles has given me the notes of one case, and it is the only one he can, in his extensive experience, recollect to have met with, of a partial dislocation of the lower part of the tibia and fibula backwards, and has also shewn me the cast he had taken of the leg. In this case the tibia seemed thrown partially backwards, from the articular pulley of the astragalus; the fibula was unbroken, and was also carried backwards with the tibia; the foot, measured from the instep upon its dorsum, was longer than that of the opposite side, the heel was shorter and less pointed, the space in front of the tendo Achillis, near to the os calcis, was partially filled up, and a hard swelling occupied the lower and back part of the tibia, which was evidently formed by a quantity of callus, which had cemented together the fragments of a fracture of the lowest part of the tibia; the leg was shorter than the opposite limb.

It would have been interesting to have learned the precise manner in which this accident had occurred; but as to this, or the immediate symptoms which followed the injury, I could get no satisfactory information. The man did not apply to Stevens's Hospital until the bones were united in their new and faulty position. Besides the partial dislocation backwards of the tibia, this bone with the outer malleolus of the fibula was inclined somewhat outwards; and the man walked lame and most awkwardly on the outer edge of the heel and foot, the inner side of which was somewhat curved inwards.

I have had occasion to notice a displacement of the tibia backwards on the os calcis, in a case where the astragalus sloughed in consequence of a compound injury to the external malleolus and ankle-joint; but such a case is different from that now under our consideration, although the possibility of such an occurrence should not be lost sight of.

2. *Morbid anatomy.* a. *Acute inflammation of the synovial membrane* of the ankle-joint produces changes in the synovial fluid of the articulation both in quantity and quality, and alterations very generally in the appearance and structure of the membrane; I say very generally, for I have known an exception to the rule, in a case* of acute synovitis of the ankle-joint which caused the death of the patient in fifty hours from its first onset; during the whole of the time the patient never slept nor ceased to complain of the agonizing pain of the ankle-joint. At the post-mortem examination, before the skin was removed, the extensors of the toes were observed to be displaced by the fluid which distended the synovial sac of the articulation, and fluctuation was now, as during life, to be felt in two tumours which existed in front of the two malleoli; the interior of the joint was occupied by a turbid oily synovial fluid; no false membrane existed, and if there had been increased vascularity during life, no trace of it was discoverable at the time of examination: increased quantity with altered quality of the synovial fluid were the only deviations from the normal condition which could be noticed. Portions of the synovial membrane are, however, occasionally found covered with false membrane. Pus has also been found in the joint, sometimes laudable, sometimes fœtid, and of a brownish red colour; the membrane has been found thickened, and has afforded evidence of increased vascularity, and even in some points has presented a villous appearance. In very young subjects I have known acute inflammation of the ankle-joint in a few days extend itself to the epiphysis, and produce separation of it from the shaft of the tibia; and in such cases a displacement of the shaft inwards, and of the epiphysis and foot outwards, occurs from the action of the muscles, as in Pott's luxation. Acute inflammation commencing in the synovial membrane of the ankle-joint sometimes extends farther than this: there have been cases in the Richmond Hospital, and the specimens have been preserved in the museum, of acute synovitis of the ankle in which the inflammation extended through the vascular junction of the epiphysis and shaft of the tibia, and having occupied the cellular junction of the periosteum with the anterior and inner surface of the tibia, soon ended in the formation of pus and lymph, which detached from the bone its immediate covering, and produced effects which terminated in the death of the patient. I have seen this detachment of the lower epiphysis of the tibia in an infant six days old, the result of acute

* Je n'ai jamais vu de luxation du pied en avant, dans les fractures du peroné et de l'extrémité du tibia.—Annuaire Médico-Chirurgical, 1819, Paris, p. 159.

* See Dublin Journal, vol. iv. p. 1.

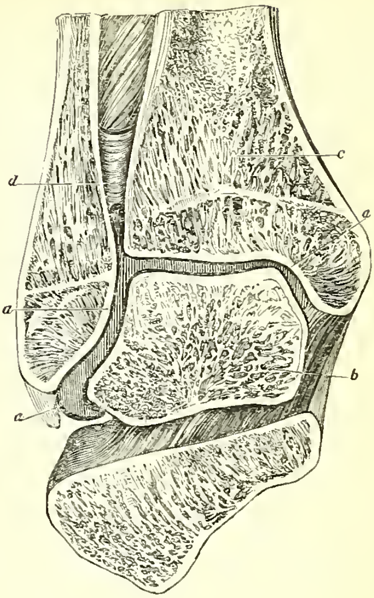
synovitis, with purulent deposition in the joint, and in a young man aged twenty, but have not observed it ever to occur in older subjects; and conclude that it is one of the consequences synovitis of the ankle-joint, which is only to be noticed at an age when the epiphyses are not yet consolidated with the shaft of the tibia.

In these very acute attacks of inflammation, its ravages are seldom confined to the structure which seemed to be the '*point du départ*' of the disease; the cartilages are in some cases removed from the tibia, fibula, and upper surface of the astragalus with astonishing rapidity; the porous surface of the bones has also been found exposed, and their substance to afford evidence of its having been in a state of inflammation. Surgeons should ever bear in mind, that the synovial membrane of the ankle-joint passes very far forwards on the upper surface of the astragalus, even as far as within a few lines of the junction of this bone with the os naviculare, so that an accidental wound high upon the instep might very readily give rise to a fatal synovitis of the ankle-joint. Moreover, by an experiment on the dead subject, it may be shown that a very slight direction too much upwards of the edge of the knife when the operation of partial amputation, according to Chopart, is performed, may wound the most anterior part of the synovial sac of the ankle-joint, and the consequences of such a mishap might prove fatal, or at all events greatly aggravate the ills which even without such cause too frequently follow Chopart's operation.

Again, the synovial membrane extends very low down, even to the lowest point of the inner side of the peroneal malleolus, along the outer or fibular surface of the astragalus (*fig.* 61, *a*).

It has very frequently happened to the writer's knowledge, that inflammation commencing in the body of the os calcis, or in the fibrous or synovial tissue of the articulation between the os calcis and under surface of the astragalus, has crept up to the ankle-joint by this route between the fibula and astragalus; when, therefore, operations and cauterizations are performed by surgeons to cure the carious state of the os calcis, the close contiguity of such an important articulation as that of the ankle should be recollected. The great proximity of the ankle-joint to that between the under surface of the astragalus and os calcis can only be estimated by making a vertical section of the tibia, fibula, astragalus, and os calcis, passing transversely across these bones and through the malleoli, as may be seen in *fig.* 61; and if a subject be selected in which the epiphysis has not been consolidated with the rest of the bone, a useful view may be had illustrating many of the preceding practical observations, and explaining clearly how inflammation, traumatic or idiopathic, once established in the ankle-joint, can pass through the epiphysis to the periosteum of the tibia; and originating either in the body of the os calcis, or in some of the structures composing the articulation between this bone and the under surface of the astragalus, can be propagated to the ankle-joint: such a view as this will shew the necessity of considering, in connexion, the normal and abnormal state of these important articulations.

Fig. 61.



b. *Chronic disease.*—The effects of chronic diseases on the tissues composing the ankle-joint are next to be considered; these are various, and may be referred to the influence of specific diseases, such as gout, syphilis, struma, rheumatism, &c.; but the effects of most of these on this particular articulation need not here be discussed, as they will be sufficiently dwelt on elsewhere in this work (see JOINT): we deem it, however, right to enter somewhat into detail in the description of those morbid appearances of the ankle-joint which are supposed to be of a scrophulous origin, and which are denominated white swelling of the ankle-joint. The external characters of the affection are pretty much those in common with the same melancholy disease, in whatever articulation of the extremity it is situated; the swelling, at first soft, and appearing in front of each malleolus, seems divided into two by the extensor tendons; after a time it becomes more solid, and assumes somewhat of a globular form; here as elsewhere, however, it does not completely surround the joint. The limb above is wasted and the heel is retracted; the foot is œdematous, and the toes are pointed downwards, no motion of flexion or extension can be communicated to the foot; but when the bones are moved laterally, an unnatural motion is communicated to the foot, and a grating of rough and carious surfaces in advanced cases can be felt: the sides of the swelling are studded over with numerous fistulous orifices, from which even now a thin sanious matter can be pressed; a probe introduced passes either directly through one or other of the malleoli, or by a circuitous route into the interior of the joint through the sinuses, which are, as it were, the excretory ducts leading from the interior, and conducting out the sanious and sabulous matter which proceed from the degenerated cartilages, synovial membranes, and bones of the diseased joint. The skin is thin, soft, and shining, and moveable on the surface, except where the fistulous orifices exist.

The anatomical characters of this disease in its advanced stage affecting this articulation we have many opportunities of observing. When the superficial coverings of the swelling are removed, the fat is remarked to be consistent and yellow, the cellular tissue interposed between the ligaments, tendons, and muscles is infiltrated with a viscid, semi-fluid, spongy, homogeneous mass; sometimes this tissue becomes so thick, and is so connected with the lateral ligaments of the ankle-joint, and so interposed among their softened fibres, as to render a clean dissection of these last impracticable; so that the ligamentous and cellular structures around the joint appear to have undergone a species of fibro-cartilaginous degeneration; the viscid glairy matter infiltrated around the joint with the tumefied ligaments are the parts which cause the principal swelling, and give to the fingers examining it that deceptive feeling of fluctuation which characterises the white swelling wherever situated.

The few muscular fibres to be found near this joint are pale and of a gelatinous appearance, being infiltrated with the same matter as that which pervades the more superficial structures. The tendons, nevertheless, preserve their natural colour and consistence. The periosteum will be found much thickened and easily detached from the bone.

The bones of the joint, and those in its vicinity, are very usually more or less atrophied, and have undergone a process of degeneration; notwithstanding, however, what has been said on high authority to the contrary, these bones are occasionally enlarged and expanded; they have lost much of their specific gravity, their spongy tissue is softened, yellowish, and easily penetrated by a knife, and filled with a matter resembling adipocere, or a yellow semi-fluid fat.

The heel it has been noticed is elongated, and the foot measured from the tibia to the toes on the dorsum is shortened very generally, and pointed downwards. Dissection discovers the cause of this frequent phenomenon in a partial dislocation of the tibia forwards on the astragalus, the softened ligaments allowing the action of the gastrocnemii and solæi to drag the whole foot backwards. In the interior of the articulation, a more or less considerable quantity of a sanious matter is found; while the cartilages covering the end of the tibia and fibula, and surfaces of the astragalus, are softened, adhere but slightly to the bones, and have been partially removed, leaving exposed the porous structure of the latter.

The arteries, veins, and capillaries present no peculiarity, except that the naturally white ligamentous tissue is more freely supplied than usual with red vessels. The neurilema of the posterior tibial nerve is evidently much thickened, so as to give it an appearance of enlargement; the small nerves around the joint seem also hypertrophied.

(R. Adams.)

ANNELIDA, (a generally adopted, but barbarous latinization of the French term 'Annélides,' from 'Annellus,' a little ring; ought rather to be written 'Annulata' or 'Annellata.')—The natural group of Annelida comprehends all the invertebrated animals which have a soft body divided into transverse segments or rings; a distinct central nervous system disposed in the form of a longitudinal gangliated chord, blood coloured (generally red), and contained in a system of appropriate and very distinct vessels; and, lastly, organs of locomotion, consisting either of fleshy appendages provided with bristles, or of bristles only; or of a prehensile cavity situated at each extremity of the body; but never of articulated members, as in the Arachnida, Crustacea, and Insecta.

The establishment of this class is due to Cuvier. Prior to him, Pallas, Müller, and Otho Fabricius, had made observations of great interest on the animals of which it is composed; and we find in the writings of the author of the Miscellanea Zoologica the most happy ideas respecting the natural relations which these animals bear to one another. Nevertheless, these works had at first but little influence on the classification of the Invertebrata, and for a long time naturalists persisted in following the method of Linnæus, who united under the term Vermes, the Mollusca, Zoophyta, and Annelida, and dispersed the latter in three different sections of that great class; confounding some with the Entozoa (intestinal worms), others with the Acephalous Mollusca, and others again with the Testacea.

It was in the work entitled "Tableau Elementaire de l'Histoire Naturelle des Animaux," published in the years 1797-8, that M. Cuvier laid the first foundation of a natural distribution of invertebrated animals. He collected together in the class Vermes the species which more lately have constituted the groups of Annelida and Entozoa, and established in it the two divisions corresponding to those which are generally adopted at the present day. Having subsequently determined the presence of red blood in the leech, and having investigated the circulating apparatus in these animals, Cuvier separated the "red-blooded" from the "intestinal" worms, and constituted for the former a distinct class, to which Lamarck afterwards gave the name of "Annélides," which has been generally adopted, and is used at the present day by most naturalists.*

This classification being based essentially on anatomical structure, has been adopted by Lamarck, Dumeril, Savigny, Leach, Latreille,

* See Cuvier, Bulletin des Sciences par la Société Philomathique, an vii. et x. Lamarck, Discours d'ouverture du cours des Animaux sans Vertèbres prononcé en Mai 1806, et Histoire des Animaux sans Vertèbres.

&c., but is not received by all zoologists of the present day. M. De Blainville, in his methodical distribution of the animal kingdom, has adopted another plan. Taking the exterior organs for the base of his system, this naturalist divides the articulate animals, which he terms "Entomozoaires," into seven classes, of which the penultimate, viz., the "chétopodes," comprehends the Annelidans provided with locomotive bristles, and of which the last, viz, the "apodes," is composed of the Annelidans destitute of those organs, together with the planariæ and intestinal worms.*

The general plan of organization exhibited in the animals which are grouped together by Cuvier under the name of "vers intestinaux," and the numerous affinities which connect the planariæ and several helmintha to the Annelida, appear to us fully to justify a partial adoption of the innovations introduced by M. De Blainville, and to indicate that the natural position of the white-blooded worms is by the side of those with red blood, at the bottom of the sub-kingdom of articulate animals; whilst in the system of Cuvier the Annelida are placed at the head of that great division of the animal kingdom, and the entozoa are left among the zoophytes. But, on the other hand, similar reasons appear to us to oppose the adoption of the divisions which M. De Blainville has proposed for the articulate animals. That zoologist, in fact, establishes a distinction between his chetopoda and apoda as wide as between the former and the insecta, arachnida and crustacea, and thus separates from the setiferous annelidans to place among the intestinal worms the hirudines, which approximate to the former and deviate from the latter in many of the most important points of their organization; for example, in the existence of a gangliated nervous system.

This arrangement does not appear to us to accord with the spirit of a natural classification, in which the several divisions ought to be indicative of the different degrees of importance which the modifications of the animal organization present.

In the present state of science the class Annelida ought in our opinion to be preserved nearly as it was established by Cuvier, but should be joined with the entozoa and rotifera, to form a great division of the sub-kingdom articulata, distinct from the natural group, consisting of insecta, myriapoda, arachnida, and crustacea. The affinities, indeed, between the setiferous annelidans and the hirudines are too close to admit of their being arranged in separate classes; and, on the other hand, every day discloses new facts of a nature which demonstrate that the vermiform animals pass from one to another by almost insensible gradations. Thus the researches of M. Dugès on the planariæ show how closely their structure approaches that of certain red-blooded worms, and the distinction founded on the colour of the nutritious fluid no longer suffices to separate them; for on the one hand it is proved that the colour of the blood is yellow and not red in some of the annelidans properly so called; while on the other hand I have recently observed on the shores of the Mediterranean an animal which differs from the genus prostoma only in the possession of red blood. We now know intestinal worms which have a circulation and a vascular system as well formed as that of the annelida, which they already resemble so much by their outward form. The absence of a rudimentary nervous system in the entozoa is called in question by skilful anatomists. Lastly, the excellent works of Ehrenberg on the infusoria of the class rotifera prove the analogy that exists between these minute beings and the articulate animals generally, but more especially to the annelida.

The differences which the annelida present among themselves have necessitated their division into many secondary groups or orders. In the latest work* that has been published on the classification of these animals, they have been divided into four orders, under the names of *Annelida errantia*, *Annelida tubicola*, *Annelida terricola*, and *Annelida suctoria* (suceuses). This classification is based on the combination of the modifications which exist in the structure of these beings, and does not materially differ from that proposed by M. Cuvier in the Règne Animal, and by M. Savigny in the great work on Egypt.

The following is a table of the principal characters which distinguish these groups.

First Order.—Annelida errantia.

Body, with soft appendages (cirri, branchiæ, or antennæ), generally disposed over the whole length of the animal, and not collected towards the cephalic extremity.

Feet generally very distinct, armed with *setæ* or bristles, which have very rarely the form of hooks.

Head generally distinct, and provided with eyes, antennæ, and a retractile proboscis, often with jaws.

(This order, which nearly corresponds to that of the *Annelida dorsibranchiata* of Cuvier, comprehends the genera *Aphrodita, Polynoë, Polyodontes, Acoetes, Sigalion, Palmyra, Amphinome, Chloeia, Euphrosyne, Hipponoë, Eunice, Onuphis, Diopatra, Lysidice, Lombrinereis, Aglaura, Œnone, Nereis, Syllis, Hesione, Alciope, Myriana, Phyllodoce, Nephtys, Goniada, Glycera, Aricia, Aonis, Ophelia, Cirrhatulis, Peripatus, Chetopteras, Arenicola.*)

Second Order.—Annelida tubicola.

Body, with soft appendages, for the most part collected together at the cephalic extremity.

Feet, almost always of two kinds, generally deprived of cirri, and armed with hooked bristles.

Head not distinct, without eyes, antennæ, pro tractile proboscis, or jaws.

(This order corresponds to that established by Cuvier under the same name, and includes the

* See the Bulletin de la Soc. Philomathique, 1818; De l'Organization des Animaux par M. de Blainville, tom. i. table 7; and the article 'Vers' of the Dictionnaire des Sciences Naturelles, tom. lvii.

* See Classification des Annelides et description des espèces qui habitent les côtes de la France, par MM. Audouin et Milne Edwards, tom. ii. des Recherches pour servir a l'Hist. Nat. du littoral de la France.

genera *Serpula, Sabella, Terebella, Amphitrite, Hermella*, and *Siphostoma.*)

Third Order.—Annelida terricola.

Body, completely destitute of soft appendages.

Feet, scarcely or not at all distinguishable, and represented only by some bristles.

Head not distinct, without eyes, antennæ, or jaws.

This order comprehends the genera *Clymena, Lumbricus, Naïs, &c.*

In the classification of M. Cuvier it is united to the Hirudinida to form the order *Annelides abranches.*

Fourth Order.—Annelida suctoria.

Body destitute of bristles for locomotion, completely apodous, and without soft appendages. A prehensile cavity in the form of a sucker at each extremity of the body.

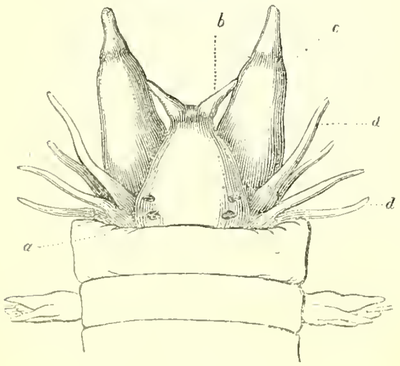
Head, not distinct, but generally provided with eyes and jaws.

This order is composed of the family of *Hirudinida*, and of the genus *Branchellion.*

External conformation.—The Annelida have always an elongated, generally cylindrical, and vermicular form; sometimes, however, they are flat or more or less oval. The body is composed, as we have already observed, of a series of rings, not of a horny or calcareous texture as in the majority of insects and crustacea, but membranous and separated from each other only by a transverse fold of the integument; as is seen in certain larvæ. The number of these rings is occasionally very considerable (some *nereida* have more than 500), and in many annelida it varies considerably in different individuals of the same species, and seems to increase with age. In some instances these segments are subdivided into two or more transverse bands by furrows.

In general each ring supports a pair of members, and when an apparently single segment gives origin to a greater number of these organs, it is easy to perceive that it results from the union of many rings blended together. The two extremities of the body are sometimes dilated in the form of suckers (in the suctorious annelidans), but in general nothing of the kind exists, and the anterior extremity either resembles the rest of the body, or it terminates in a head more or less distinct (as in the nereida, see *fig.* 62), often supporting eyes (*a*), and filiform appendages called antennæ, (*b,c*), the number of which is generally three, four, or five.

Fig. 62.



The *mouth* is situated at the extremity of the body, and in the acephalous annelida is directed forwards, but in the cephalous species this opening is situated below the base of the head. The anus is placed at the opposite extremity, and is almost always found on the dorsal aspect of the body. A certain number of Annelida are completely apodous, and do not present the least trace of an appendage on any of the segments of the body (the hirudinidæ). Others exhibit on either side many rows of bristles, which fulfil the office of feet (the terricolæ). In others, again, the bristles of which we have spoken are supported on a fleshy tubercle more or less prominent, and more or less complicated in structure, and to these organs the name of *feet* is applied.

The feet of the Annelida, when they present the maximum of development of which they are susceptible in that class of animals, are composed each of two very distinct portions, placed one above the other, and appertaining the one to the dorsal, the other to the ventral arch of the ring. (See *fig.* 63, which represents one of the feet of an amphinome.) M. Savigny, who was the first to study with due care the zoological characters furnished by these appendages of the annelida, gave to these portions of the feet the names of dorsal oar (*a*) and ventral oar (*b*) (rame dorsal et rame ventral). Sometimes these oars are pretty distant from one another, (*fig.* 63.) sometimes they are separated only by a shallow fissure (*fig.* 64. which represents the foot of a nereid), and occasionally they are so intimately blended together that they can hardly be dis-

Fig. 63.

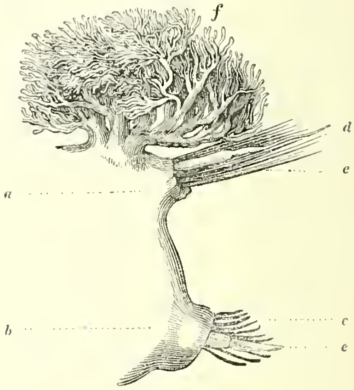
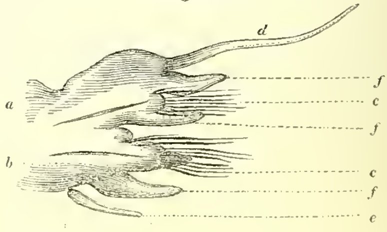


Fig. 64.



tinguished, and form, as it were, but a single organ; lastly, there are cases in which only one of the oars would seem to be developed. If one were disposed to compare the locomotive system of the annelida with that of the other articulate classes, the ventral oar should be regarded as analogous to the members which in the Crustacea, Insects, &c. are variously modified to constitute the legs, the jaws, or the antennæ: and the dorsal oar ought to be considered as representing the appendages, which, though wanting in the greater number of articulate animals, yet acquire a considerable development on the last two rings of the thoracic segment of most insects and constitute the wings. In this particular the annelida afford an example of the greatest uniformity in the development of the appendicular system in the articulate division of the animal kingdom.

Each oar is essentially composed of a fleshy tubercle more or less prominent, which supports different productions of the integument, incloses the bristles (*c*), and which is more especially designated by the name of foot. Towards the base of the setiferous tubercle there is generally a membranous appendage, sometimes filiform, sometimes lamelliform, called the *cirrus* (*d*, *e*); lastly, it is also above the margin and near the base of these organs that the branchiæ (*f*) take their origin, but in general it is only the dorsal oar that supports them. All the above parts may exist simultaneously, but it often happens that one or more are atrophied to a greater or less degree, or are altogether deficient; and this either along the entire body or on certain segments only. Thus in the terricolous annelida there are no cirri; in the hermellæ they are present on the ventral, but not on the dorsal oar; while in the cirrhatulæ the reverse obtains.

In most of the annelida errantia the setiferous tubercle of both oars is wanting on the first rings which follow the head, whilst the cirri assume a very great development, and form the appendages termed by systematic authors *tentacular cirri.* (*Fig.* 62, *d.*)

A similar modification may be frequently remarked in the composition of the appendicular system of the last ring of the body, and thence results a certain number of filiform productions called styles. Lastly, the antennæ of the annelida, which must not be confounded with the antennæ of insects and crustacea, may also be considered as representing the cirri of the dorsal oar of those rings, the union of which constitutes the head.*

The annelida pass in general a somewhat stationary life, and a great number among them remain constantly buried in the earth or enclosed in tubes formed by the mucus which is secreted by the skin, and which, while hardening, commonly agglutinates together fragments of shells and sand. The formation of these sheaths is very quick. I have seen them fabricated in the course of a few hours. Sometimes they are of extreme tenuity, occasionally they are as tough as thick leather, and there are some which possess very considerable hardness and are composed in great proportion of carbonate of lime, like the shells of mollusca. In the greater part of these animals locomotion is produced by general undulations of the body determined by contractions of a layer of muscular fibres extending from one ring to another, and fixed to the inner surface of the skin. But in other species the change of place is effected by the action of the feet, of which we have spoken; or by the contraction of the tentaculæ which surround the mouth, as in the terebellæ, and which, by shortening themselves, drag on the body of the animal in the same manner as the arms of the cephalopods: lastly, by the action of the suckers with which the extremities of the body are furnished.

The bristles (*fig.* 63 and 64, *c*,) with which the feet of the annelida are provided, do not serve merely as little levers to facilitate their movements, but are also offensive arms, and their structure is very curious. They differ considerably from the hairs of other articulate animals, which are nothing more than small tubular prolongations of the epidermic layer. By their mode of connexion with the integuments and their mode of formation they appear to approach the hair of mammalia, but their disposition is of a more complicated nature. They are inclosed in sheaths provided with muscular fibres, by the aid of which the animal can protrude and retract them again: in general, also, they are not merely simple conical filaments, but their extremity is often shaped like a harpoon, a lance, or a barbed arrow, and the annelidan uses it to inflict a wound upon its enemies.*

Sensation.—Tactile sensibility is considerable in these animals, and it seems to reside principally in the antennæ, the cirri, and the tentacula. They do not appear to possess a sense of hearing, and there are many among them which do not manifest any sign of sensibility to light; but in others, eyes (*fig.* 62, *a*,) exist, the number of which is sometimes very considerable, but the structure very simple. They are coloured points, (generally black,) and situated on the dorsal aspect of the head or on the cephalic sucker. In the setiferous annelida there are never more than two pairs, but in the hirudinidæ or leeches their number often increases to eight or ten. The anatomy of these eyes has recently been studied by Professor Müller of Berlin, and according to his researches it would seem that these organs do not contain a crystalline lens, or a transparent body analogous to the vitreous cones of

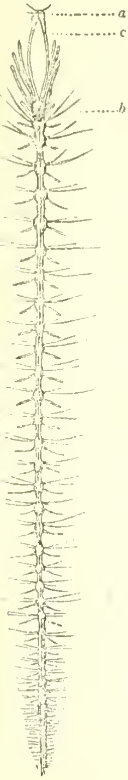
* For further details regarding the external structure of the annelida the reader may consult the excellent work of M. Savigny, intitled "Système des Annelides," principally of those found on the coasts of Egypt and Syria; the article 'Vers' of the Dictionnaire des Sciences Naturelles, tom. lvii. by M. De Blainville; and a more recent publication on the same subject inserted in the Annales des Sciences Naturelles, tom. xxviii, xxix, and xxx, and in the second volume of the 'Recherches pour servir à l'Hist. Nat. du littoral de la France, par MM. Audouin et Milne Edwards.'

* See Observations sur les Poils des Annelides considerés comme moyen de Defense, par MM. Audouin et Milne Edwards, op. cit. tom. ii. p. 31.

the crustacea and insecta, but consist simply of a terminal ganglion of the optic nerve covered by a layer of black pigment and placed immediately beneath the integument, which is thin and transparent at that part.*

Nervous system.—In like manner the nervous system of the annelida is very simple. It occupies the middle line of the ventral aspect of the body, and consists of a double series of minute ganglions of medullary matter, more or less intimately united or even blended together, and equal in number to the number of rings. (See *fig*. 65. representing the nervous system of the aphrodita aculeata). The ganglions give origin to lateral branches, and are connected together by two chords of communication, sometimes separate, sometimes united into a single trunk, so as to constitute a longitudinal chain extended through the entire length of the body. The first of these ganglions (a) is lodged in the head, or at least at the anterior extremity of the animal, in front of or above the digestive tube; the rest are placed below that canal; whence it results that the two nervous chords which form the media of communication between the cephalic ganglion and the first of the sub-œsophageal series pass along the sides of the œsophagus, and form around that canal a species of collar or ring; a character which is common to all the articulate animals.†

Fig. 65.



Organs of digestion.—The alimentary canal in the annelida extends from one end of the body to the other, and has an external communication at both extremities. The mouth is generally provided with a projectile proboscis, which is formed by the anterior portion of the digestive canal, which can be inverted and protruded like the finger of a glove, and possesses muscles for the express object of effecting these movements (see *fig*. 66, which represents the proboscis of a *phyllodoce*, and *fig*. 67, that of a *nereis*). The surface is frequently beset with small papillæ, and its extremity armed with

Fig. 66.

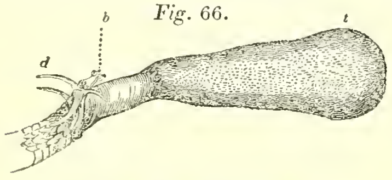
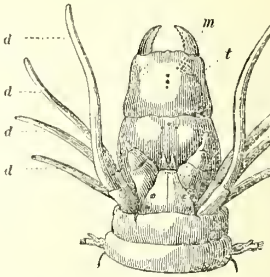


Fig. 67.



horny jaws (m), the disposition of which varies in different genera. It is to be observed that these jaws are almost always placed laterally like the mandibles of other articulate animals, and cannot act upon one another in the direction of the axis of the body, as in the vertebrata, but are not to be regarded as analogous to the mandibles and maxillæ of insects and crustacea. In their structure, the jaws of the annelida approximate rather to the solid plates with which the interior of the stomach in some crustacea is provided, and to the hooks which arm the mouth of certain gasteropodous molluscs. This conformation of the oral apparatus is met with only in the annelida errantia; in the annelida terricola there is scarcely a vestige of a proboscis, and never any teeth or jaws. In the annelida suctoria, the mouth, which is placed at the bottom of the cephalic sucker, is also occasionally protruded in the form of a small tubular proboscis, and in other species its margins are armed with little horny jaws; lastly, in the annelida tubicola, nothing of the kind is to be seen, but in general the superior border of the mouth forms a sort of projecting lip, which is provided with long tentacles, sometimes simple and filiform, sometimes pectinated and resembling tufts. In certain erratic annelida, the *Agliope*, for example, there are also found around the mouth small tentacula, which are quite distinct from the tentacular cirri, and which appear to be analogous to the appendages of which we have just made mention.

The œsophagus which succeeds the proboscis or mouth presents nothing worthy of notice, but it is in general quite distinct from the stomach. The conformation of the latter organ varies much. Sometimes the stomach is a simple enteroid tube (as in the nereida and terebellæ); sometimes it is composed of two pouches, of which the first is membranous and may be compared to a crop, while the second is muscular and is analogous to a gizzard, as, for example, in the *lumbrici*, *thalassemæ*. In other cases the stomach presents on either side a succession of enlargements which have in general the form of rounded cells, but which sometimes constitute sacs or vast and much elongated cœcums, (as in some hirudines, *figs*. 68 and 69.) Lastly,

* See Annales des Sciences Nat. tom. xxii.

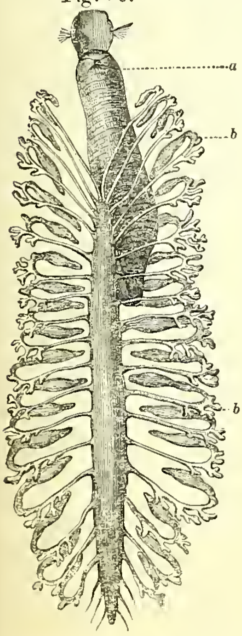
† See Cuvier, Anat. Comparée, tom. i.; Treviranus, über der stachlichten Aphrodite, Zeitschrift für Physiologie, 3 Band; Moquin Tandon, "Monograph. des Hirudinés," Morrem, "Sur le Lombric," &c.

Fig. 68.

Fig. 69.

we may observe that these cœcums are replaced by blind canals, either simple or ramified; thus in the arenicola, or sand worm, we find that there communicate with the second stomach two cœcums terminated by a soft point, with thick parietes of a yellow colour; and in the aphroditæ the stomach opens on either side into a score of membranous appendages, which commence of very contracted diameter, but afterwards insensibly become dilated and divide into many branches: (see *fig.* 70, *a*, the retracted proboscis, *b b*, the appendages.) This type of structure leads to that which is manifested in the planariæ, and also approximates to what one sees in the parasitic arachnida.

Fig. 70.



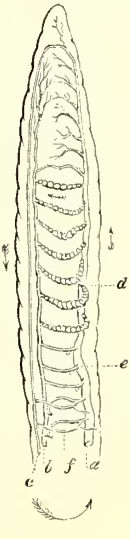
The intestine which succeeds the stomach is generally narrow, and in the majority of the annelida extends in a direct line to the anus. In some species, as the amphitrites, it presents a greater or less number of convolutions. There does not exist in these animals a gland which can be regarded as a liver, properly so called: the appendages which are grouped around the stomach in the *arenicolæ* may, indeed, be biliary vessels analogous to those of insects rather than true cœca; but in the earthworms and many other annelides the bile would seem to be secreted by a peculiar organ of a yellow colour and pulpy texture, which surrounds like a sheath a great part of the digestive canal. Lastly, in certain annelida, as, for example, the thalassemæ, there exists on either side of the œsophagus a small organ, which would seem to have a secretory office, and may very probably be a salivary gland.*

Circulation.—The blood in almost all the annelida differs from that of every other invertebrate animal by its red colour; sometimes, however, this fluid has scarcely a tinge. According to M. De Blainville the blood of the aphroditæ is yellow, and MM. Mayor and Gosse, of Geneva, assert that the circulating fluid of the genus *clepsina*, one of the hirudinidæ or leech-tribe, is even altogether white. When the blood of an annelide is examined with the microscope it is seen to contain circular globules, but of a much larger size, and in far less number than in human blood: it coagulates after rest like the blood of the higher animals, but it appears to contain a very small proportion of fibrine.

The blood circulates, as we have already stated, in peculiar vessels, which its red colour renders easily distinguishable.

The vascular system has been best studied in the earthworm: above the alimentary canal there runs along the entire length of the body a contractile vessel (*fig.* 71, *a*,) which is consequently dorsal, and in which the blood passes generally from behind forwards, sometimes in large waves, sometimes by small quantities propelled by the successive contractions of the divisions which this vessel forms through its entire extent. A portion of the circulating fluid then passes into another vessel (*c*), which originates at the anterior extremity of the one abovementioned, and which runs backwards along the ventral surface of the body below the nervous column, from which circumstance it has been called the sub-nerval vessel by Dugès. But the greater part of the blood which is contained in the dorsal vessel, instead of following this channel, passes into seven or eight pairs of large lateral branches composed each of a series of dilatations or rounded ve-

Fig. 71.



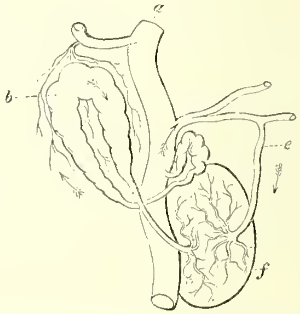
* See Willis, 'De Animâ Brutorum;' Pallas, 'Miscellanea Zoologica;' Cuvier, 'Anat. Comp.' Treviranus, op. cit. Moquin Tandon, op. cit.; Dugès, op. cit.; Home, 'Lectures on Comp. Anat.'

sicles (*d*), which are highly contractile. These 'moniliform vessels' are placed in a situation corresponding to the ovaries: they are directed downwards and open into a ventral vessel (*b*), which occupies the middle line of the inferior aspect of the animal, following the same track as the sub-nerval vessel, but situated less superficially. Its parietes are contractile, and it may be seen alternately dilating and contracting simultaneously at every part along the whole of its extent. The blood flows into this ventral vessel from before backwards, and leaves it to re-enter the dorsal vessel by passing through the branches (*e*) which ascend perpendicularly to join the latter, on either side of the alimentary canal, which they thus embrace, and to which they furnish a great number of ramifications. The blood contained in the sub-nerval vessel flows equally from before backwards, and ascends to re-enter the dorsal vessel by lateral channels (*f*), analogous to the anastomosing vessels which we have just described, but situated more superficially than those. These superficial transverse or *dorso-abdominal* vessels, as they are termed by M. Dugès, severally receive a large branch from their corresponding deep-seated *dorso-abdominal* vessel, and distribute to the skin a number of ramifications which appear to be specially destined to bring the blood into contact with the oxygen necessary for respiration.*

In the genus *naïs* the moniliform vessels, which in the earthworm perform in some degree the office of a composite heart, seem to be replaced by a single pair of wide veins, which are contractile and analogous to a divided heart, and both the superficial and deep-seated transverse vessels by which the blood ascends to the dorsal trunk seem to rise from one and the same ventral trunk; so that the circulatory apparatus is more simple in these annelida than in the earthworms. The same plan pervades the sanguiferous system in the other setiferous annelidans, in which the branchiæ are distributed throughout the entire length of the body; but when these organs are collected together at a determinate point of the anterior extremity of the body it is a little different. Thus in the terebellæ the ventral vessel is seen to bifurcate and to form two lateral branches which have the form of an arch, and which, after having passed over the sides of the œsophagus, re-unite above that tube to form a single trunk. This trunk reaches the anterior extremity and gives origin to three pairs of primary branches, which descend to the vesicular receptacles at the base of the branchiæ, and distribute the blood to these organs.

In the leech-tribe the vascular system, on the contrary, is more complicated, for the sanguiferous circle is composed of four longitudinal trunks, and the branches which bring them into communication with each other. Of the four longitudinal vessels two occupy the dorsal and ventral aspects of the mesial line, and two the sides of the body. The dorsal and ventral trunks communicate together by dorso-abdominal branches corresponding to each segment of the body. The lateral trunks also render to the dorsal trunk a series of dorso-lateral branches, and, moreover, mutually communicate by a series of abdomino-lateral branches which glide transversely beneath the nervous chords. The dorsal and ventral vessels are evidently analogous to those which we have designated by the same names in the earthworm and naïs; and the lateral vessels may be compared to the sub-nerval trunk of the earthworm, except that, instead of being single and situated in the mesial line, they form a circle in which the blood undulates sometimes in one direction, sometimes in another, but always pursuing an opposite course in the two canals. Lastly, in addition to the above 'general circulation,' there is observed in the leech-tribe something analogous to the 'lesser circulation,' (*fig.* 72):

Fig. 72.



this is effected in the branches (*b*, *e*) of the dorso-lateral vessels (*a*), which are for the purpose of bringing the blood into contact with the aerated water contained in the small membranous vesicles (*f*) situated at the sides of each segment of the animal, and opening externally upon the inferior aspect.*

Respiration.—From what has been said of the mechanism of the circulation in the annelida, it will be seen that respiration must be effected either in the vesicles above mentioned, or on the surface of the body. Such in fact is the case; the skin is in general the seat of that function; but in the greater number of instances, the integument, instead of maintaining the same texture throughout, and acting upon the air in the same manner at every point of its extent, presents at particular spots peculiar modifications, and thus gives rise to special organs of respiration called 'branchiæ.'

The branchiæ of the annelida are almost universally membranous appendages, highly vascular, fixed to a certain number of the feet of the animal, or inserted upon the back near the base of these organs.

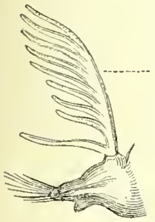
In the nereida and some other congeneric annelida, the appendages which are designated branchiæ, and which in fact seem to be in an

* See Dugès, 'Recherches sur les Annelides abranches,' Annales des Sciences Nat. t. xv.

* See Moquin Tandon, op. cit. Dugès, op. cit.

especial manner subservient to respiration, are simply a kind of papillæ or laminated cutaneous productions very little or not at all subdivided, attached either to the extremity or base of the feet and distributed in an almost uniform manner over the entire length of the body, (*fig.* 64, *f*, *f*, *f*.) In the *eunice*, and other allied genera, their position is the same, but they assume the form of an elongated filament, furnished with a series of prolongations of a similar filiform shape, disposed like the teeth of a comb, and traversed longitudinally by a canal filled with red blood, (*fig.* 73, *f*.) In the amphinomian family, as in the former groups, these branchiæ are placed on almost every segment of the body, so that these organs form along the whole extent of the back a double row; but here their structure is more complicated, for the filaments are extremely subdivided, (*fig.* 63, *f*.) In the *arenicolæ*, the form of the branchiæ is almost the same as in the amphinomes, but they are limited in their position to the middle segments of the body. In the genus terebella the branchiæ are also highly ramified vascular appendages to the integument, but their number is inconsiderable, and they are all inserted near the cephalic extremity of the back. In the serpulæ, the membrane which forms a sort of thoracic disc near the cephalic extremity of the body, ought to be regarded as an organ of respiration, and it is probable that the tentacles surrounding the mouth like a crown of plumes are subservient to the same function.* In the hirudinæ respiration is in part effected by the external skin, but there exists in these annelida a series of small membranous sacs, which communicate externally each by a minute orifice situated on the ventral aspect of the body: these sacs derive from the numerous vessels which ramify upon their parietes a considerable quantity of blood. Water penetrates into these organs and seems to subserve a true respiratory purpose. These sacs are commonly denominated 'pulmonary sacs,' and some authors think that they receive into their interior atmospheric air in a gaseous form. Their number varies from fifteen to twenty, and it may be observed, when a living leech is irritated after being recently removed from water, that a small quantity of liquid escapes from their apertures.

Fig. 73.



In the *lumbrici terrestres* there is in like manner found in each segment and on either side of the digestive tube, an enteroid vessel folded upon itself, containing a liquid and opening outwardly by a particular pore. These sacs are less vascular than in the leeches; nevertheless there is reason to believe that they fulfil an analogous office, and perform a more or less important part in respiration. Lastly, it has been proved that in the annelida there are other pores, placed on the back, which traverse directly the dermo-muscular envelope, and communicate with a cavity intermediate to the muscles and intestines, and imperfectly divided by transverse septa, into which air or water can penetrate. This structure may, indeed, belong to the respiratory apparatus, but science does not yet possess sufficient data to solve that question. An analogous disposition has been observed in the naïs.*

Generation.— The generative apparatus is only very imperfectly understood in the annelida. It appears that all these animals are hermaphrodite, but that they cannot fecundate themselves; the intercourse of two individuals being necessary for the accomplishment of the act of generation. It is in the earthworm and leech that this part of their anatomy and physiology has been most completely studied.

In the leeches the sexual apertures are placed at the inferior surface of the body towards the anterior third, and separated from one another by the intervention of five segments. The anterior aperture belongs to the male organs, and at the season of reproduction a filiform and highly contractile penis is observed to be protruded from that part, (*fig.* 74, 75, *a.*)

Fig. 74.

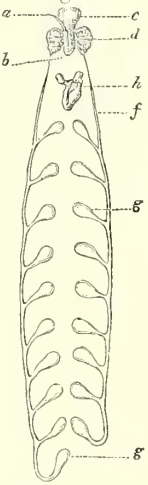
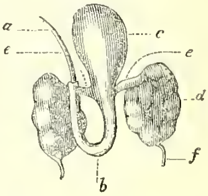


Fig. 75.



This communicates internally with a narrow cylindrical canal (*b*), which in its turn opens into a kind of whitish vesicle of a pyriform shape (*c*) commonly called the *vesicula seminalis*. On each side of this vesicle there is an oval whitish body (*d*) composed of contorted tubes filled with a whitish liquid: each of these organs is a testicle; and they severally give origin to a slender *vas deferens* (*fig.* 75, *e*) of the same colour, which opens into the vesicula seminalis. Lastly, from the posterior extremity of the testicle, another filiform duct (*f*) is continued, which passes backwards on each side of the nervous cord, and gives origin to a series of pedunculated vesicles filled with a whitish fluid similar to that which

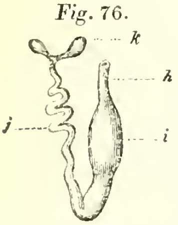
* See, for additional details, the works already cited of Savigny, De Blainville, and Audouin and Milne Edwards.

* For the structure of the pulmonary sacs, see Willis, op. cit. Thomas, 'Mémoires pour servir a l'Histoire Naturelle des Sangsues.' Home 'Lectures on Comp. Anatomy,' Moquin Tandon, op. cit. Morren de Lumbric. terrest. Dugès, op. cit.

is contained in the rest of the apparatus. These organs (*fig.* 74, *g*) are generally regarded as accessory vesicles, and they vary both in number and form in different species.

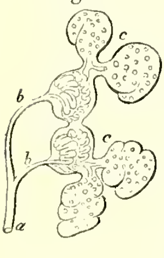
The female apparatus is of much less magnitude, but also presents a sufficiently complicated structure: it is situated between the two canals leading to the accessory vesicles of the male apparatus, and is a little posterior to the penis. The external orifice, of which we have already spoken, communicates with a short canal (*fig.* 74 and 76, *h*), of a greyish colour, which leads to a sort of pouch (*i*). This, according to some authors, is analogous to an uterus, but in the opinion of other naturalists is merely a *copulative vesicle* for the purpose of retaining the fecundating liquid which is there deposited by the male in the act of copulation. This sac is bent upon itself, and a duct (*j*) may be observed to be continued from the anterior extremity which leads to the ovaries (*k*): these are small whitish bodies two in number, and in close approximation to one another.

Fig. 76.



In the earthworm, the only parts that can be regarded as male organs are some sacs or vesicles varying in number from two to seven, and situated in a longitudinal series on either side of the ventral aspect of the body towards its anterior extremity. Each of these vesicles adheres to the parietes of the splanchnic cavity, by a small canal opening directly outwards by pores placed on the posterior and inferior part of the corresponding ring: there is farther a canal of communication, which is continued directly from one vesicle to another of the same lateral series; and at the season of copulation there is found in the interior of these organs a viscid liquid abounding with seminal microscopic animalcules. The outlets of the female apparatus occupy the sixteenth segment of the body, and are continuous internally with two narrow canals directed forwards, and situated on the internal side of the above mentioned vesicles. Having reached the ovaries, each of these canals (*fig.* 77, *a*) divides into two branches (*b*), which bend inwards and terminate by a globular enlargement (*c*). This is seen with the assistance of the microscope to be itself formed by a continuation of the canal puckered up into numerous folds, which are enveloped in a common membrane. To each of these enlargements are appended a pair of ovaries, the entire number of which is consequently eight, four on either side. The colour of these ovaries is whitish, their texture pulpy, and their interior is beset with numerous minute vesicles, which are the ova. At the period of copulation the ovaries are filled with a whitish fluid, which is probably the spermatic secretion, but it is not easy to comprehend how the male apparatus can introduce it into that part.* According to Redi, the ova, after being detached from the oviduct, pass along the whole extent of the body towards the vicinity of the anus, whence they are expelled by two orifices stated to be near the termination of the alimentary canal or to open in its interior. According to Montegre it is the fœtus and not the ovum which traverses the body to escape by the above passages, and the lumbrici according to this view are viviparous. This statement has been adopted by many authors without perhaps sufficient examination; but, according to recent observations by Dugès, it would seem not to be correct, and that what have been regarded as the young of the earthworm are in fact a species of intestinal worm.

Fig. 77.



In the naïs the male organs are less numerous than in the lumbrici, but differ very little in other respects. They consist of a single pair of vesicles opening externally by a winding canal, which terminates by a small fissure on the eleventh segment of the body. The ovaries are disposed in four principal masses, between which there winds a long oviduct, of which the extremity can be protruded outwardly like a penis.†

In some annelida, as the *clepsina carena*, the ova are developed and hatched before exclusion, so that the young are born alive; but most of the class are oviparous, and what is very remarkable, the same ovum sometimes incloses the germs of many embryos: this is the case in the earthworm, each ovum of which produces two individuals, and in the leech the ova contain severally as many as eighteen embryos. One might at first view suppose that the same circumstances obtained in the naïs; but what appears to be an ovum with multiplied germs is in reality nothing more than an aggregate of simple ova.

Reproduction.—Some annelida not only perpetuate the race by the ordinary modes of generation, but enjoy the singular faculty of producing new individuals by a transverse division of the body. A naïs or an earthworm cut in two and placed under favourable circumstances, will continue to live, and each moiety will become, in appearance at least, a perfect animal. This fact, which was first determined by Reaumur and Bonnet, has since been verified by M. Dugès, Sangiovanni, and many other observers: the anterior portion of the animal reproduces a new tail, and the posterior portion developes a head.

That faculty which the two portions of the earthworm's body possess of manifesting the vital properties independently of one another, and even after having been separated, may be explained to a certain degree by the known structure of these animals and

* See Willis, Dugès, &c.

† See Dugès, op. cit.

the general laws of physiology. With the exception indeed of the generative organs which are concentrated in a peculiar part of the body, it is easy to observe that each segment of the body is almost the exact repetition of all the rest: they all possess the same organs, and, however the total number of rings may vary, there results no change of any importance in the general structure of the animal. Now it may be laid down as a law in physiology, that a parity of organization necessitates a similitude of action; and it results that as in depriving an earthworm of a given number of segments no organ is removed of which it does not still retain the analogue, no function is completely destroyed; and consequently that if such a mutilation should weaken the vital action, it does not change its nature. This holds good for both the segments of the animal: each continues to possess all the organs essential to individual existence, and consequently if their resisting energy be sufficiently great, there can be no reason why they should not continue to live independently of one another, and become two distinct worms.* But if the anterior moiety thus becomes a perfect animal, it is probable that this may not happen to the posterior portion, but that the new individual formed by this part will always continue deprived of generative organs. For the anterior moiety retains exclusively the reproductive organs of the original individual, and there is nothing which authorizes the belief that the earthworm possesses the power from being simply mutilated, of reproducing the whole apparatus on any part of the posterior moiety. This, however, is a circumstance which it would be easy to determine.

From the sketch that we have given of the organization of the annelida, it will be seen that there exists in this branch of zoology many hiatuses. Anatomists, in fact, have hardly paid attention to any but the leech, the earthworm, and the naïs, and we possess only a vague notion of the internal structure and physiology of the erratic and tubicolar species; their comparative study would form an interesting subject of research.

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(*H. Milne Edwards.*)

* See the article Organisation of the 'Dictionaire Classique d'Histoire Naturelle,' and the Introduction to my 'Elemens de Zoologie.'

ANUS, (in anatomy,) from Anus vel Annus, a round, a circle, (syn. *ostium recti, podex, culus.* Gr. πρωκτος. Fr. *anus.* Germ. *After.* Ital. *ano.*) is a term commonly applied to the lower extremity of the rectum: properly speaking, it is the inferior orifice of the alimentary tube, through which, in the higher orders of animals, the excrementitious portion of the food, as also the excretions from the digestive apparatus, are discharged; for obvious reasons it is endowed with powers to assist in expelling, as also with the faculty of retaining these for a considerable time: such opposite but important qualities would infer the existence of a somewhat complicated muscular apparatus, more or less under the influence of the will, as also a structure in other respects worthy of attention.

The presence of an anus indicates a complex system of digestive organs; hence in many of the inferior or simpler classes of the invertebrate division of animals it is absent, and in many of the superior of this division, as well as in several of the vertebrata, it presents considerable variety as to structure, function, and position. In some of the zoophytes, such as the infusory animalcules there is no central digestive cavity, and of course no distinct outlet. In them absorption takes place by imbibition through pores into cells, in a manner somewhat similar to a sponge; and most probably excretion (if any occurs) takes place through the same orifices. In others of this class, such as the acalephæ, where a rudimental cavity appears in the body of the animal, a single orifice admits the food necessary for its support, and the excrementitious portion (if any) is ejected through the same opening. In the actiniæ, also, where a distinct stomach exists, and where the retained matter obviously undergoes certain changes, the one orifice serves the two-fold purpose of admission to the food, as well as of exit to its residuum. Even in some of the echinodermata, as the asteriæ, in which the digestive apparatus is more developed, the central cavity becoming more complex, the latter is still but a cul de sac, which can be protruded at the mouth, the only orifice it presents. In other species, however, of this class, the anus appears; thus in the English echinus, where the masticating apparatus is so remarkable, this opening exists on the surface of the animal, opposite to the mouth.*

In the sipunculi the anus opens near the mouth, and in the holothuriæ near the respiratory organ.†

In the several families of the articulata, viz. insecta, crustacea, and vermes, the anus exists, and is always found at that end of the animal opposite to the mouth, and most generally on its inferior surface.

In the mollusca it is also present, but it holds situations singularly differing in the different orders and genera of this class; thus in the cephalopoda, as the cuttle-fish, the rectum opens into a sort of cloaca, which is situated before the neck, and which also receives the semen and ova, as well as the secretion from the ink-bag. In the gasteropoda, as the slug, it is generally found near the pulmonary cavity. In the patella or limpet, however, it opens on the head, and in the doris on the back, surrounded by a delicate fringe, a sort of branchial tuft. In most of the acephala, except the oyster, the rectum extends along the back of the animal, beneath the hinge, and above the respiratory organs; it then passes through the heart, and opens above the posterior muscle of the shells, into the cavity of the maulle, or between its edges, the anal opening presenting the appearance of a fleshy disc or sphincter.

Among fishes the anus varies, in the osseous and cartilaginous divisions of this class; in the former it usually presents the appearance of a round opening leading into a longitudinal groove; it is placed in front of the anal fin, and of the urinary and genital aperture, contrary to what occurs in all other vertebral animals. In the cartilaginous fish, as the ray and shark, this groove is deeper, and has the appearance of a true cloaca, through which are discharged, as in the sepiæ and in birds, not only the alvine, but also the urinal and seminal excretions.

In reptiles the anus serves as the opening of a cloaca, or common receptacle of the residuum of the food, as well as of the urine, semen, or ova; in the batrachia, as the frog, it is situated at the end of the back, and therefore above the body of the animal. In the chelonia, as the tortoise, it is under the tail. In the sauria and ophidia it is a transverse cleft, but in the salamander it is a longitudinal fissure with two prominent lips.

* Home's Lect. on Comp. Anat. vol. ii. p. 76.
† Cuvier's Comp. Anat. t. iv. p. 143.

In birds the rectum expands above the anus into the cloaca, which also receives the terminations of the ureters, the ends of the vasa deferentia, and the penis (when the latter exists); also the openings of the oviducts, and of the bursa Fabricii. In all the mammalia the rectum terminates in a distinct anal opening, which is placed at the posterior or inferior extremity of the trunk, directly under the origin of the tail, and usually in a direction opposite to the mouth, and in all it is placed behind, and not, as in fish, before the urinary and sexual orifice; in some few of the quadrumana, as the mandril, it is directed upwards. In almost all mammalia it is a distinct orifice, giving passage to the fæces only; in the beaver and sloth, however, the rectum and urethra have a common termination. The monotrematous animals also, such as the echidni and ornithorhynci, form a complete exception to this statement; in these singular and anomalous creatures a single opening gives exit to the fæcal and urinary secretions, and also subserves sexual purposes. (See INTESTINAL CANAL.)

ANUS (in human anatomy). In the present article we propose to examine not merely the structures which immediately bound this opening in man, in their normal and healthy state, as well as in their abnormal and diseased conditions, but we shall also examine the parts which enclose and surround it, and which can exert an influence, direct or indirect, on its functions; that is, we shall consider the anatomy, normal and abnormal, of the parts contained in the *Anal Region*.

The Anal Region is synonymous with the posterior portion of the perinæum; its triangular area is denoted by the following outlines: the apex, which is posterior and superior, is marked by the extremity of the os coccygis; its base, which is before and below the latter, is defined by an imaginary line extending transversely from one tuber ischii to the other, and each side is denoted by a line drawn from the last named process to the point of the coccyx: these lateral boundaries correspond to the margins of the glutæi maximi muscles, which overlap the inferior or the great sacro-sciatic ligaments; the base or the transverse line before mentioned, separates the anal from the anterior perineal or urethral region: in the adult male this line will be found to be about three inches, or nearly three inches and a quarter in length; in the female it is about half an inch longer, and more certainly so if the individual examined have borne children; great variety, however, has been found to exist in this measurement, the extremes of which may be stated at two and four inches. In children under twelve years of age this transverse diameter of the perinæum is considerably less, in consequence of the extreme narrowness of the pelvis prior to puberty.

The anal region contains the lower portion of the intestinum rectum, several muscles, and fasciæ, some nerves and vessels of importance, and an abundance of adipose substance. The quantity and consistence of the adipose substance found in this region vary considerably in different individuals at the several periods of life, and under various conditions of health; a fact most important for the surgeon to bear in mind, inasmuch as this diversity causes corresponding differences in the physical characters which this region presents under these particular circumstances. In children, and in the female, in youth and middle age, as also in the robust and healthy male, this region will be found plump, or convex around the anus, whereas in the emaciated, the sickly, or the old, it often presents the very opposite appearances; and a proportional difference may be observed in the depth of the perinæum, or in the distance between the neck of the bladder and the surface: the greatest extremes of this difference have been found between two and four inches, a circumstance which bears materially on the lateral operation of lithotomy.

So much of the *Rectum* as lies beneath the cul de sac of the peritoneum, may be considered as appertaining to the anal region, and must, therefore, be noticed at present; below the reflection of that membrane, this intestine descends obliquely forwards between the sacrum and bladder, in the male as far as the prostate gland, and in the female as far as the vagina; it is there on a level with the inferior extremity of the coccyx, and then it bends downwards and backwards, and ends in the anal opening; the perinæal portion of the Rectum, therefore, is convex forwards and concave towards the coccyx; hence in introducing into this intestine the bougie, enema pipe, or even the finger, it should be directed at first upwards, and forwards, and then upwards and backwards: in the child, however, this precaution is not necessary, as the course of this intestine is not so much curved, the name of Rectum being then more correctly applied than in the adult.

In order to examine the several parts contained in the anal region, the thighs should be fully separated, flexed, and fixed on the pelvis; the first object which attracts attention is *the Anus.*

This opening is situated in the median line, at the bottom as it were of a deep excavation, which is bounded on either side by the tuberosity of the ischium, with the superincumbent muscular and adipose substance; in the erect position it appears at a great depth from the surface, in consequence of the approximation of the nates. In the adult the anus is from one inch to an inch and a half distant from the point of the coccyx, and three inches from the arch of the pubis; it is in some measure, but not perfectly, fixed in its situation, anteriorly by an indirect attachment to the interosseous or triangular ligament of the urethra, and posteriorly by a dense fibrous tissue, which forms a sort of raphè between it and the coccyx, and to which the muscles and integuments adhere. In the natural and healthy state, the anus presents the appearance of a small rounded, or rather elliptical orifice, whose border is thrown into numerous small plaits, or rugæ, which during the extended state of the opening are effaced; these rugæ are occasionally so deep as to admit of the escape of a small quantity of fluid. As the skin approaches the margin of this opening it becomes very fine and delicate, is gathered into those several radiated folds or plaits, which sink into it, and in the same manner as at the other outlets of the body, it becomes continuous with the lining mucous membrane of the intestine, there being no exact line of demarcation, except that of an increased vascularity, to distinguish the one from the other. This plaited condition of the skin which lines this opening arises from the close contraction of the subjacent muscle, and is doubtless designed to admit of the more easy dilatability of the anus during defœcation; this opening, however, is never equal to the diameter of the rectum at a little distance above it. In the child the integument surrounding the anus is smooth and red, in the adult it is of a deep brown colour and studded with several fine hairs, which, however, are usually absent in the female. In this situation also the cutaneous follicles are very distinct and numerous, but not so prominent as in the scrotum; they secrete a mucous or sebaceous matter which gives to the skin a shining or oily appearance, and adapts it to the functions of the part: from the absence or from the vitiated condition of this secretion, painful and troublesome excoriations not unfrequently ensue. In the healthly state the margin of the anus feels firm and resisting, and together with the surrounding muscles forms a floor or support to the inferior part of the pelvis, in the centre of which floor the rectum and its contents are maintained, and on either side a mass of cellular and adipose substance.

Muscles.—The muscular apparatus connected with the lower extremity of the rectum consists of the superficial and the deep *sphincters* of the anus, also the right and left *levatores ani*, to which may be added the two *transversi perinæi*, and the two *coccygæi* muscles.

The first two, namely, the *sphincter* muscles, surround the anus, and may be regarded as a modification, or as a particular development of the general circular muscular tunic, which is continued around the whole alimentary tube from the mouth to the anus, and which in different situations exhibits a considerable increase in colour and consistence, for example, in the lips, around the fauces, the œsophagus, the pylorus, &c. The name of these muscles indicates their principal function, while the other muscles which have been alluded to proceed from certain fixed points to be inserted into the lower extremity of the rectum, and must, therefore, rather serve to retain the anus in its situation or to restore it to its natural condition, when in the exercise of its functions it has been considerably dilated, or slightly displaced by the expulsive efforts of the diaphragm and abdominal muscles. We shall first examine the descriptive anatomy of these individual muscles, and then consider their several powers or purposes in the economy of the surrounding organs. Although there are two sphincter muscles of the anus, yet this name is generally applied to the more superficial of these; we shall distinguish these muscles by the names of *sphincter ani cutaneus* vel *ellipticus*, and *sphincter ani profundus* vel *orbicularis*.

Sphincter ani cutaneus (σφιγγω, constringo,) *coccygeo-anal*, *sphincter externus*, *constrictor ani*) is the first muscle which meets the eye of the anatomist in the dissection of this region. It may be exposed by dividing the integuments from the coccyx to near the back part of the anus, and thence extending an incision on each side, and about half an inch distant from the edge of this opening to its forepart, whence it should be continued indefinitely along the median line of the perinæum; the integument should then be carefully dissected off from either side of this elliptical incision.

The muscle thus exposed is thin and flat, of an elongated and elliptical form, and cleft in the *centre* to embrace the opening of the anus; it arises posteriorly fleshy and cellular from the point of the coccyx, and from a tense fibrous or cellular tissue, called the *recto-coccygæal ligament*, which extends from the coccyx to the back part of the anus, where it divides and is lost in the cellular tissue on either side. From this origin the fibres of the sphincter collect into a rounded fasciculus, which proceeds forwards and downwards, increasing in size, and at the back of the anus divides into two bands which pass one on either side of this opening, each spreading out till it is an inch or even more in breadth; again converging in front of the anus, these bands unite into a fasciculus, which in the male is very long and passes forwards and upwards between the skin and the acceleratores urinæ muscles, to be partly *inserted* into the median line of the superficial fascia of the perinæum, and partly confounded and interlaced with the transversi perinæi, and with the muscles which cover the bulb of the urethra; through the medium of these last it is even attached to the common cellulo-tendinous central point of the perinæum, between the rectum and the bulb, whereby it is enabled to act on this part of the urinary canal. This anterior insertion is very variable in different persons; in some it stops abruptly at the bulb, while in others it continues to run forwards between the skin and the acceleratores as far as the dartos, in which it terminates. In the female this anterior fasciculus is much shorter, and ends in the sphincter or constrictor vaginæ; in the male its attachment to the muscles of the bulb is often deficient, so that in the course of the dissection, when the superficial fascia has been removed, this extremity of the muscle will be found detached and its insertion isolated. The entire of the inferior surface of this muscle is in contact with the integuments, its superior surface is related to the levatores ani, acceleratores urinæ, and transversi perinæi muscles; in front of the anus it is confounded with the two latter, and immediately behind it with the formerly named muscles; its external border is of uncertain extent, and is imbedded in adeps, while its internal edge is in close relation with the delicate inflected anal skin, being separated only by a fine cellular tissue. This muscle is composed entirely of fleshy fibres, occasionally intersected by cellular and imperfect tendinous bands; these fibres are placed in concentric arches, those of opposite sides unite at acute angles, and sometimes interlace before and behind the anus; the fasciculi are frequently separated by considerable intervals, so that they appear like different muscles; some of the internal fibres assume a circular arrangement; in the female this muscle is shorter, broader, and more rounded, particularly in front. In structure and appearance this muscle presents great diversity; in some it is red, strong, and large, in others, so pale and weak as to be difficult of perfect demonstration; it is also probable that during life great differences exist as to its power of contraction.

The *use* of this muscle is obviously to close the anus, the skin of which it throws into small rugæ; hence when the sphincter is paralysed, there is incontinence of the contents of the rectum; the most internal fibres will tend to close the opening more perfectly than the external or elliptical, which will reduce it rather to a cleft or fissure; this muscle can also raise the anus somewhat, and at the same time draw back and compress the bulb of the urethra; it will also express the secretion from the anal glands and follicles. The sphincter ani may be properly said to belong to the class of mixed muscles, both as relates to its structure and function; as to the former, its paleness, scattered fibres, connection with the commencement of the mucous surface, and absence of true tendon ally it to the muscular system of organic life; while on the other hand the parallel direction of its fasciculi, and the arrangement of many of the latter in the surrounding adeps, assimilate it to the muscles of voluntary motion. In its functions also it appears to border on the province of each division of the muscular system; thus without the efforts of the will, or even without any internal cognizance, it continues in a state of almost permanent contraction, and as unconsciously relaxes when the functions of the part impress upon its sensibility the necessity of so doing; while on the other hand the will can exert a considerable control over its powers, and can cause it to contract with considerable and continued energy, as well as throw it into a state of atony and relaxation. Although this muscle belongs to the same class with the other sphincters, the orbiculares oris and palpebrarum, yet it manifests a considerable difference in its vitality. The natural and, therefore, the usual condition of these other sphincters is relaxation; hence the mouth continues open, and partly from the same cause too, the eyelids are apart; whereas the natural condition of the sphincter ani when at rest is contraction, and hence the anal opening is always closed, although the muscle is still capable of contracting with considerably more energy when any of the contents of the rectum suddenly approach the orifice, or when any irritation exists in its vicinity.

The *Sphincter ani internus* vel *orbicularis* (*Sphincter intestinale*, Winsl.) is of much less extent than the former, and is situated more deeply; it is closely connected to the mucous membrane, or the fine lining integument, and appears a particular development of the circular fibres of the intestine, like those which surrouud the pyloric extremity of the stomach. This circular muscular ring consists of several fine and pale fasciculi of fibres, which are closely connected together, and when contracted form a thick ring around the intestine immediately within the anus; this muscle may be exposed either by detaching the lining membrane which is but loosely attached to it, or removing the rectum from the subject, everting and distending it. The mucous membrane being then detached, the muscle will be distinct; its upper border is continuous with the circular fibres of the rectum, and a distinct cellular line separates it from the cutaneous sphincter; anteriorly it is connected with the levatores ani muscles.

The action of this muscle must be to assist the former sphincter in closing the lower extremity of the rectum and supporting its contents; in the process of defæcation it assists in the expulsion of the residual portions of the fæcal matter, by the sudden or almost spasmodic action which succeeds its relaxation; moreover, it strongly opposes the entrance of any foreign body by the anus; so that from its power of resisting the ingress or egress of any substance, it may be considered as constituting a perfect pylorus.

The subcutaneous adipose tissue in perineo is very abundant in some situations; close to the anus, or between the sphincter and the skin, there is but very little; hence abscesses but seldom form there, except of very limited size, such as small furunculi, or as the result of circumscribed inflammation in some of the follicles around the opening; whereas at either side of the anus and rectum there always exists a considerable quantity of cellular and adipose matter, the former remarkable for the large size of its cells, which are intersected by irregular bands or fibres from the perinæal fascia, and which give the whole some degree of elasticity; the adipose substance is abundant, very soft, loose, sometimes reddish, and fills those large spaces which exist on either side of the rectum. In no part of the body do abscesses so frequently form as in these ischio-rectal spaces; and as such abscesses are very generally attended with consequences tedious, troublesome, and dangerous, it may be right to make a few remarks on the anatomy of these regions.

Each *Ischio-rectal space* is a deep triangular hollow, the base being situated towards the integuments, the apex towards the cavity of the pelvis; the outer side is formed by the ischium, and the inner by the rectum with its muscles; this intestine, together with the attachments of the levatores ani behind and before, separates the two spaces from each other, but the cellular membrane of one side communicates with that of the opposite, and hence in cases of diffused or extensive suppurations, the fluid is occasionally observed to pass from one side to the other; anteriorly the transversus perinæi, and posteriorly the coccygeus muscles bound this hollow. Each of these triangular recesses is lined on all sides, except towards the skin, by fasciæ, a view of which may be obtained by dissecting out of either all the contained adeps. There may then be observed near the apex, or the deepest part of the recess, a strong and tense aponeurotic line, which is the inferior folded surface of the pelvic fascia, which in this situation sends off its inferior or descending layer; this latter immediately divides into two laminæ, an internal and an external; the latter is called the obturator, the former the ischio-rectal fascia; the former is very strong and distinct, the latter very thin and cellular.

The *obturator* fascia descends a little obliquely outwards and is inserted into the falciform process of the great sacro-sciatic ligament, and into the tuberosity and ramus of the ischium. It is very dense, being composed of strong aponeurotic fibres, and it conceals and separates from the perinæum the obturator internus muscle, and the internal pudic nerves and vessels, the perinæal and hemorrhoidal branches of which pierce it as they proceed to their destination. The internal layer, or the *Ishio-rectal fascia*, is much weaker and more cellular than the last; from the before-mentioned aponeurotic line it descends obliquely inwards along the lower and outer surface of the levator ani as far as the sphincter, when it becomes thin and cellular, and is lost in the surrounding adipose tissue. Thus, by the unfolding or division of the inferior layer of the pelvic fascia into these two laminæ, the obturator and ischio-rectal fasciæ, these recesses are completely lined, and by the gradual degeneration of the last named aponeurosis into cellular and fibrous bands, which interlace in every direction, the large mass of adipose substance is enclosed and supported, whilst a general firmness and elasticity is imparted to the whole region. Towards the posterior part of each of these regions a cul de sac is enclosed between these fasciæ and overlapped by the glutæus maximus, on the surface of which the fasciæ become extended, and ultimately lost. A somewhat similar but smaller cul de sac exists anteriorly behind each transversus perinæi muscle. An inspection of the Ischio-rectal spaces will serve to explain not only the great size to which abscesses here attain, but also the difficulty in effecting a cure when they have been of long standing and of considerable magnitude; the constantly-varying form of the rectum on one side, the immoveable surface of the pelvis on the opposite, a muscle above, and the integuments below, all tend to prevent the possibility of effecting any permanent apposition between the sides of the cavity, while very generally the state of the constitution is equally unfavourable to any healthy action in the part. These several facts have impressed surgeons with the propriety of opening all such abscesses in a very early stage, otherwise a large cavity will be formed, the rectum denuded, and very frequently opened by ulceration.

Transversi perinæi muscles (*Ischio-peri-*

neal).—This pair of small muscles extends in a direction nearly parallel to the anterior border of the anal region; each *arises* from the inside of the tuber ischii, passes inwards, forwards, and downwards to join its fellow in the median line of the perinæum, where it is also partially attached to the cutaneous sphincter of the anus, and to the acceleratores urinæ muscles, or in the female to the constrictor vaginæ. These muscles are very unequal in appearance in different subjects; in some they are feeble and indistinct, in others very strong, and sometimes divided into two on one or both sides, the additional or minor muscle being superior and anterior. In the female these muscles are often found more distinct than in the male, but even here much variety exists; in many subjects they appear to be simply composed of some of the anterior and partially detached fibres of the middle portions of the levatores ani muscles. The transversi perinæi muscles form the bases of the two lateral triangular regions contained in the anterior or urethral perinæum, and one of them, the left, is necessarily divided in the lateral operation for lithotomy; they are surrounded by much adipose matter; two arteries, both branches of the internal pudic, take a course parallel to them, — viz., the superficial transverse perinæal, and the deep transverse, or the artery of the bulb. These muscles are enveloped between the layers of the perinæal fasciæ. The superficial layer, which is continuous with the Ischio-rectal, covers them in their course forwards to the urethral muscles, and the deep layer, or the triangular ligament of the urethra, which is continuous with the external or Ischiatic layer or obturator fascia, lies between them and the pelvis. These muscles, therefore, will have the effect of making tense the different perinæal aponeuroses, and thus they can support, strengthen, and compress generally the parts in the perinæum; they can also compress, and thus assist in clearing the orifice of the anus, at the same time that they draw back and raise this part, somewhat in the same manner as the levatores ani muscles. According to some anatomists these muscles are considered as dilators of the bulb of the urethra, as well as of the vagina; but it is more than doubtful whether they can exert any such action. When these muscles are divided, the base of the deep perinæal fascia, or triangular ligament of the urethra, is exposed. This will be observed to have some influence in maintaining the rectum and anus in their situation; its posterior border, being attached to the levatores ani muscles, and to the bulb of the urethra, serves to maintain a close connection between these parts, which is still further effected by the interlacement of the muscles of the anus with those which cover the bulb. (See Perinæum.)

Levatores ani (sous-pubio-coccygien).—This pair of broad, thin, flat, and nearly square muscles form a septum somewhat broader above than below, between the pelvis and perinæum, which, together with the aponeuroses covering its upper and lower surfaces, and with the coccygeal muscles and the triangular ligament of the urethra, completely intercepts all communication between these two regions except through the natural passages for the urethra, vagina, and rectum. Although these muscles are described as two, there appears no good reason for the division, for the fibres of opposite sides have a common insertion, partly into the circumference of the rectum and partly into a middle cellulo-tendinous raphé before and behind that intestine. It appears more correct to consider these muscles as one circular muscular septum extended across and within the lower opening of the pelvis, concave towards this cavity, and convex towards the perinæum. The fibres attached by their circumference to the interior of the pelvis, and converging thence towards the median line of the perinæum, are inserted into and around the rectum; in fact the muscle resembles the diaphragm in form, in the circumference being its origin or fixed attachment, and the central portion being its insertion, also in its being perforated for the transmission of certain parts; the analogy only fails in the absence of a central tendon, and in the fibres being principally inserted into the parts passing through it. The fact, however, of there being an interruption in the origin of this muscle in the middle line both before and behind, in which respect again there is a resemblance to the sternal and vertebral deficiences in the diaphragm, is the cause of its being described as consisting of a right and left muscle, which distinction, it should be observed, is only an artificial one, for during life the fibres of both sides act together, and in all respects constitute but a single muscle.

The origin of the levator ani muscle may be exposed by tearing the peritonæum from the parietes of the pelvis, together with a considerable quantity of loose cellulo-adipose membrane. The recto-vesical layer of the pelvic fascia should then be divided near to the neck and sides of the bladder, and carefully raised towards the wall of the pelvis. The muscle will then be seen to *arise* on each side by three attachments, which, however, form one continuous semicircular line extending from the pubis to the spine of the Ischium; its anterior portion is attached to the back part of the pubis, a little above its arch, and immediately below the anterior vesical ligaments by short aponeurotic fibres commencing a little distance from the symphysis, and extending outwards as far as the notch in the thyroid hole; its second or middle attachment is to a strong tendinous arch, which extends from the pubis to the spine of the Ischium, and which is formed at the separation or junction of the pelvic fascia into its superior or recto-vesical layer, and its inferior or perinæal layer; its third or posterior attachment is to the spinous process of the ischium. All the fibres pass downwards and towards the median line to their *insertion;* the inferior border of this muscle is shorter but thicker than the superior. The fibres of the first, or pubal portion, descend a little obliquely backwards on each side of the prostate gland and membranous portion of the urethra, and converging beneath the latter are inserted in common between the bulb and the fore-part of the rectum into the central point of the perinæum; these portions in their descent present a well-defined edge inwards or towards the median line. The middle, or aponeurotic portion, is broad and thin above, the vesical fascia adhering so closely to it as to render its separation difficult. As it descends it increases in thickness, expands close to the rectum, and is inserted into the coats of that intestine, intermingling with its longitudinal fibres, and with the sphincter ani; in the female it is intimately attached to the vagina also. The posterior or Ischiatic portion passes almost transversely inwards, and is inserted into the coccyx, and into the cellulo-tendinous line which extends from the latter to the rectum; some fleshy fibres are continuous from one muscle to the other. This portion of the levator ani is more aponeurotic than the preceding, and its posterior border is connected to the Ischio-coccygæus muscle. The external or inferior surface of this muscle is inclined downwards, and is more or less related to the obturator and ischio-rectal fasciæ, to the glutæus maximus and transverse perinæal muscles and vessels, and to the mass of anal fat. The internal or concave surface looks upwards, and is closely covered by the vesical fascia, below which it is in contact with the rectum, bladder, prostate gland, and urethra, or with the uterus and vagina. This muscle is disposed on the rectum in the same manner in the female as it is in the male; the fibres are also intimately connected to the vagina.

The *action* of the levator ani muscles is two-fold, and not confined to the mere elevation of the anus, as its name would imply. First, they act as a moveable floor to the abdomen and pelvis, which can antagonize the diaphragm; these two fleshy planes being opposed to each other, can, by a slight action of one or both, materially alter the perpendicular axis of the abdomen, which extends between them. This axis is at its greatest length during the state of expiration, and is most diminished when both these muscles are forcibly contracting. The levatores ani, however, have less influence in effecting this change than the diaphragm; they serve chiefly to support the lower region of the pelvis and the several viscera this cavity contains against the combined protruding forces of the diaphragm and abdominal muscles in violent exertions of the body, or in forcible efforts of respiration, or in the evacuation of the contents of the rectum and bladder; and, secondly, they not only raise, but dilate the anus, by drawing out its circumference so as to overcome the sphincters; at the same time they compress and assist in emptying the rectum, particularly the dilated pouch, which is a little above the anus; they also resist the prolapsus of the mucous coat of the intestine, and raise it after it has been to a certain extent protruded by the action of the abdominal muscles. They raise and draw forward the coccyx after it has been forced back by abdominal pressure in parturition, or in the ordinary evacuation of the bowels, and further, by raising and compressing the trigonè of the bladder, they assist in expelling its conteuts, and for the same reason they can also empty the vesiculæ seminales of their fluid. The anterior portions of these muscles are intimately connected to the membranous part of the urethra, and are variously modified in different individuals and in different animals; we consider those muscular fasciculi which have been described differently by anatomical writers under different names, compressores urethræ, &c., as parts of or appendages to these muscles: these urethral portions of the levatores ani can certainly compress the membranous part of the urethra and empty its canal; they can even interrupt or suddenly stop the stream of urine, and thus they may occasionally aid the neck of the bladder in retaining the contents of that organ.

The *Ischio-coccygæi* muscles are situated at the posterior inferior part of the pelvis; they are thin, flat, and triangular, composed of a mixture of fleshy and tendinous fibres. The apex or origin of each is attached to the spine of the Ischium, and its base is inserted into all the side of the coccyx, and a small portion of the sacrum; they are partly covered by the great sciatic ligaments. The superior and posterior border is connected to the lesser sciatic ligament, and the anterior border is in part continuous with the levator ani muscle; the anterior or pelvic surface is connected to the rectum and the surrounding adipose substance. This pair of muscles appear as a prolongation of the levatores ani, and are of use in completing the inferior boundary of the pelvis; they thus support the rectum and the pelvic viscera, and they also serve to retain the coccyx and restore it to its situation when protruded by the diaphragm and abdominal muscles in the process of parturition, and in the act of defæcation, or when drawn too much forward by the levatores ani muscles. If the several muscles in this region be now partially removed on one side, the lower extremity of the rectum will become more distinct, and will be found surrounded by a quantity of loose, fatty, cellular tissue, separating it from the surrounding muscles and bones; this contains many nervous filaments and numerous bloodvessels, particularly veins. (See Intestinal Canal.) Anteriorly in the male subject a small triangular space, the *bulbo-rectal* hollow, will now become distinct; this is situated between the anus and membranous portion of the urethra; the base of it is at the skin of the perinæum; the apex at the prostate: to the last the rectum will be seen rather intimately connected. The bulb and the membranous portion of the urethra bound this space in front, and the rectum behind. (See Perinæum and Urethra.)

Rectum.—In addition to the several muscles which have now been severally noticed, and which thus serve not only to retain and support the rectum and anus, but which even enter into the structure of the former, we have further to consider the parts more immediately composing the parietes of the lower extremity of the intestine; these are the longitudinal muscular fibres,—the mucous membrane, and the submucous cellular tissue. The longitudinal fibres of the alimentary tube exist through its whole extent, but like the circular are differently modified in different situations; thus along the œsophagus they are very fully developed, also along the arches of the stomach; in both these situations the fibres are strong and somewhat red; whereas on the parietes of the small intestines they are very indistinct and pale; on the cœcum and colon they are still pale, but very distinct, being collected into three flat fasciculi or bands. On the rectum, as on the œsophagus, they are again fully developed as to thickness and number; their colour is still rather pale. In the two superior thirds of this intestine, or as low down as the prostate gland, they predominate over the circular fibres, which are internal, whereas in the lower third the latter prevail; the former terminate, some by becoming continuous or intermingled with the fibres of the levatores ani, others with the cutaneous sphincter so low as the border of the anus, and some are inserted into the submucous tissue of the intestine; these fibres are continuous superiorly with those of the colon; they serve to continue that successive series of contractions or shortenings of the intestine, which essentially assist in the process of defæcation. As the longitudinal fibres of the rectum resemble those of the œsophagus, so the inferior circular fasciculi or the sphincters are like the muscles of the pharynx, not merely in their increased strength and colour, but also in their vital power. Over the longitudinal fibres the will has no control, whereas the inferior circular are to a certain extent under its influence. Here, then, as in the organs of deglutition, we perceive the animal and organic powers still distinct as to their elementary nature, but becoming intimately, nay inseparably associated for wise and obvious purposes.

In the act of defæcation the offices of the several muscles connected with the anus may be summed up as follows:—When the contents of the rectum, particularly if of a solid consistence, are being expelled, the whole rectum descends, and the perinæum becomes prominent in consequence of the viscera being forced against it by the contraction of the diaphragm and abdominal muscles. The presence of the fæces irritates the muscular fibres of the rectum; the longitudinal fibres shorten the intestine, while the successive actions of the circular urge down the fæcal mass; these two orders of muscular fibres are the true antagonists to the sphincters. During this stage, however, the sphincters are relaxed, and the anus becomes dilated, partly by the contents of the rectum distending it, and partly by the levatores ani muscles, which are nevertheless in a sufficiently relaxed condition to allow the protrusion of the rectum and anus, while they still support the latter to a certain extent, and thus exert a sort of check against its forcible descent; they also tend to open the orifice of the anus. During this forcible expulsion, a small portion of the mucous lining is frequently protruded. The expulsion of the last portion of fæculent matter is then effected by the subsequent strong and gradual contraction of the levatores ani compressing the rectal pouch, and raising the rectum and anus to their former position, and lastly, the sudden action of the sphincters clears and closes the orifice.

The mucous membrane lining the rectum is in every respect highly organized, it is thrown into several folds, and is larger and looser than the other coats, hence portions can be easily removed by operation, and are not unfrequently detached by gangrene. As it approaches the anus, it is very red, soft, and fungous, being highly vascular, presenting the orifices of several glands, follicles, or lacunæ. It is here very loosely connected to the muscular fibres, and is frequently found thrown into irregular folds; these are protruded somewhat during defæcation, and when morbidly enlarged or thickened, are not unfrequently the source of considerable pain and inconvenience. As the mucous membrane is not contractile, these folds are necessarily increased when the longitudinal fibres of the rectum contract and shorten the intestine; they are then protruded together with the fæcal matter. Immediately above the plaited margin of the anus the skin and mucous membrane become continuous; the termination of the cuticle appears rather abrupt, just within the internal sphincter. Some describe it as continued higher up, and gradually lost on the surface. I have not been able to exhibit it satisfactorily higher than the point indicated, nor does it appear to me that it extends through this orifice by any means to the same extent as through the other outlets of the body, the mouth, nose, urethra, or vagina. In the latter passage in particular it is very distinct, even in health; and in disease, as in cases of prolapsus uteri, its development becomes considerable; whereas in prolapsus ani, that is, a protrusion of the mucous lining of the rectum, at a little distance above the anus, I have not found the protruded mass to become covered with cuticle: I have seen cases of long standing in which the surface presented the same soft, vascular tissue as it does at first. It does not controvert this statement to find tumours about the margin of the anus (hemorrhoids or polypi) covered with a thickened or developed cuticle; for in such cases the cutaneous covering is derived from the elongation of the surrounding skin, which has increased in density from exposure to the air, and from continued irritation. The same remark will apply to cases of artificial anus, no matter in what situation: in all these the villous surface, which protrudes during the peristaltic action, retains its mucous characters, and does not become covered with cuticle. From these facts it may be inferred that cuticle is never developed in any situation in which it did not originally exist, but that circumstances favour the increase or more full development of it in those situations where it naturally occurs, even though its normal condition be extremely delicate and fine.

Nerves and vessels.—The submucous tissue in the vicinity of the anus is very loose, and the seat of nervous and vascular plexuses; in the latter the venous system predominates.

A consideration of the functions of the rectum and of its surrounding muscles, its remarkable irritability and sensibility in health, as well as its sympathies in disease, would lead us to infer what dissection proves to exist, namely, that this organ is largely supplied with nerves; numerous branches are furnished to it from the sacral plexus, which is formed by the union of the inferior spinal nerves, also from the hypogastric plexus, which is chiefly composed of filaments of the sympathetic. The *sacral plexus* of spinal nerves furnishes, in addition to many others, the hemorrhoidal, vesical, and pudic branches; the hemorrhoidal nerves are directed principally towards the inferior part of the rectum, some ascend to the colon, others descend even to the sphincter ani: they divide into numerous filaments, which are chiefly distributed to the muscular fibres of the rectum and the adjacent muscles; the vesical nerves in their course to the bladder give some filaments to the rectum, and the inferior or perinæal division of the pudic nerves also send several branches to the levator and sphincter ani muscles. The *hypogastric* plexus of nerves is composed of filaments from the sacral plexus, which interlace with some from the inferior mesenteric plexus, and with numerous branches from the sacral ganglions of the sympathetic nerves. This plexus supplies the rectum, as also the other pelvic viscera; the branches accompany the bloodvessels, and are distributed principally to the mucous and submucous tissue. The cellular tissue, also, about the coccyx, and the adjacent muscular fibres receive some filaments from the coccygeal plexus of the sympathetic. This supply of nerves from these two very different sources, the one presiding over voluntary, the other over involuntary motion, corresponds with the well-known functions of this organ, and causes its muscles to be classed by the physiologist under the head of mixed muscles, that is, partaking of the common characters of the animal or voluntary, and the organic or involuntary systems. Its supply of spinal nerves serves to explain not only the influence which the will can exert over its functions, but also the impaired or altered state of its powers in case of disease or injury of the brain or spinal cord; thus irritation of the latter may cause morbid irritability and contraction of the rectum, and, necessarily, constipation of the bowels; or, again, paralysis of the spinal cord from injury or compression may lead to perfect atony of the sphincters, and to the involuntary discharge of the contents of the rectum. The general distribution of the branches of the sacral and hypogastric plexuses to the several pelvic viscera, and to the muscles, &c. in the perinæum, associates these different organs with each other, which is so necessary to their functions, and with the urinary and generative organs, connecting more particularly the muscles of the anus with the muscular coat of the urinary bladder and with the parts about its cervix. This interlacement and subsequent general distribution of these nerves serve also to establish those several sympathies which are found to exist in acute and chronic diseases of the rectum and anus, between this intestine and the other pelvic viscera. In some the uterus and vagina partake of the irritation, in others the urinary bladder is almost incessantly irritated to expel its contents; or, on the other hand, when the sympathetic irritation engages its cervix and the parts in its vicinity, the most painful retention of urine is endured. Chronic disease of this intestine is also very generally attended with occasional attacks of pain and irritation in different portions of the alimentary canal, as also with pain in the sacrum and loins, and in various other directions, which may in most cases be explained by referring them to nervous irritation extending in the course of some of the nervous communications which are found to exist in such numbers in the pelvis.

The rectum, like the rest of the alimentary canal, is freely supplied with blood. Its arteries are named *hæmorrhoidal*, and are derived from three sources, viz., the abdominal aorta, the internal iliac, and the internal pudic arteries. The superior hæmorrhoidal is the continuation of the inferior mesenteric, a branch of the aorta; the middle hemorrhoidal is derived either from the internal iliac or from some of its branches; and the inferior or external hemorrhoidal branches from the perinæal division of the pudic. The latter are destined directly to the confines of the anus, and are lodged in the subcutaneous adeps. The two former belong properly to the rectum, and are above the levatores ani muscles. These arteries divide into several small branches, which anastomose together, and form a continued chain of inosculations along this intestine, somewhat similar to that which is continued along the whole of the alimentary tube. They form a complicated vascular net-work between and within the muscular fibres, and are largely distributed to the mucous and submucous tissues. Some branches of considerable size not unfrequently descend so low even as the sphincter, particularly at its posterior parts. These are liable to be divided in operations for the cure of fistulæ, and sometimes give rise to a hæmorrhage, troublesome and difficult to restrain. In such operations the external hæmorrhoidal arteries also are very commonly opened, and bleed smartly; they can be secured, however, with much less difficulty than the divided extremities of the superior or middle hæmorrhoidal vessels.

The whole of the rectum, particularly its lower portion, is encompassed by numerous veins, which in some persons are very large and plexiform. In the perinæum, also, many venous plexuses are found in the subcutaneous adeps. The external hæmorrhoidal arteries have their external venæ comites, which run outwardly to end in the internal pudic veins (branches of the internal iliac). Some of their branches ramify around the anus, and in some cases form a plexus, in which hæmorrhoidal tumours are frequently developed; the middle hæmorrhoidal veins are uncertain as to number, size, and situation, but the superior are very large and numerous; their branches form repeated anastomoses in the submucous tissue around the intestine, and frequently present all the appearance of erectile tissue, particularly in front, communicating below with the perinæal veins, before with a plexus of vaginal or prostatic veins, and above with the trunk of the inferior mesenteric which leads to the vena portæ. This latter communication, as also the absence of valves in the portal system, has laid the foundation of the practice of applying leeches to the anal region in chronic inflammatory affections of the liver and bowels. The same facts also have been adduced to explain the frequency of hæmorrhoids, varices, and vascular congestion about the anus and rectum in cases of diseased and hardened liver, which, under such circumstances, is supposed to obstruct the circulation by impeding the returning blood through the venæ portæ.

ABNORMAL CONDITION OF THE ANUS AND NEIGHBOURING PARTS.

Congenital malformations.—The lower extremity of the rectum and anus not unfrequently present in the new-born fœtus congenital malformations, some of which are incompatible with continued existence, while others admit of protracted suffering, with great inconvenience and imminent danger to life; while, again, some may be relieved by the interference of art. Hence it is necessary to consider these anomalous appearances with a view to discriminate those which are curable from those in which all remedial attempts are totally useless. The following congenital malformations have been noticed by surgical writers, some of which have come under our own observation.

1. The anus has appeared at first view to be natural, but on a more accurate examination no canal has been found above it; and after death it was discovered that the rectum was absent, that the left colon ended in a cul de sac, and that a dense fatty substance occupied the situation of the rest of the canal. It is plain that no operative interference could avail in such a case. In some cases of this want of rectum the anus has been absent also.*

2. The anus and rectum have appeared natural, but after death it has been found that the latter was interrupted in one part of its course, and that the intestine had ended above that in a cul de sac. This state of parts must lead to the same practical conclusion as that last mentioned. In these and in such like cases of unhappy malformation, some have suggested, as a "dernier resort," the propriety of opening the intestinal canal at some point in the abdomen, so as to evacuate its contents and establish permanently an artificial anus. The proposal was first made by Littre,† of opening the sigmoid flexure of the colon in the left iliac region. A successful case of this operation is recorded as having been performed by Duset* on a boy twenty-four hours after birth: the child was reported, at twelve years of age, to be in good health, with an artificial anus established in the left iliac fossa.†

3. No anus, but the rectum has opened into, and its contents escaped either by the urethra in the male, or by the vagina in the female. This condition is an approximation to the cloaca of birds, and of some fishes. Life may continue under such an arrangement, particularly in the female, when the intestine opens into the vagina, with great inconvenience no doubt; but in the male the prognosis cannot even be so favourable, as the urethra can scarcely suffice to give exit to the fæces after some time; and as the bladder and organs in its vicinity will be subject to constant irritation. Cases are, however, recorded of life being protracted for several months; and in one case, a boy, who lived for eight months, on examination after death it was found that a cherry-stone had blocked up the passage of communication between the rectum and urethra. In such a state of parts it has been advised to cut through the perinæum in the situation of the anus, and endeavour to open the extremity of the rectum. The bladder should be previously emptied of urine, and a sound or staff be retained in it, as a guide to the operator to protect it from injury. In the other somewhat parallel condition of these parts in the female, the exit for the alvine matters is usually more free; and several cases are on record of life being continued for several years. These cases offer more encouragement for operative interference than the former. A curved probe may be passed from the orifice in the vagina into the rectum, and then directed towards the perinæum to the situation of the anus. An incision is to be then made upon it; and when the canal of the rectum is thus opened to the surface, the channel is to be kept carefully dilated, in order to oppose the natural tendency in the parts to close.

4. The anus may be open, but the contents of the intestine retained, in consequence of a congenital contraction of the rectum at some distance above, owing either to a membranous septum extending across it, or to a circular thickening and contraction. Such cases may be overlooked, and their cause remain unknown until after death: in cases, therefore, of obstinate constipation at this early age, this part should be particularly examined. Petit ‡ describes this condition, and mentions a case in which he detected such an obstruction in the rectum, about an inch above the anus. This he divided by a pharyngotome, with success. The division may be effected by a bistoury, if situated low down; or by a trochar, if at a considerable distance from the anus.

* See Dict. des Sciences Med. t. xxiv. p. 129.
† Mem. de l'Academ. des Sciences, 1720.

* Recueil Periodique de la Société de Méd. de Paris, t. iv. p, 45.
† Dict. des Sciences Méd. t. xxiv. p. 126.
‡ Mem. de l'Acad. de Chirurg. t. i. p. 385.

5. No anus, but the rectum is continued pervious as far as the integuments, which in some cases are then prominent, and of a violet colour, from the meconium appearing through in the situation which the anal opening should occupy. In other cases the skin is thick and hard, and gives no indication of the situation of the rectum. In such circumstances the surgeon must divide the integuments, either by a crucial or by a transverse and longitudinal incision, and then proceed cautiously until he exposes the distended rectum. When the skin only intervenes, the prognosis as to the result of this operation may be favourable, as the sphincters are probably perfect; but when the cul-de-sac of the rectum is deep-seated, then experience affords but little encouragement to hope for success. Death is inevitable in such cases, unless relief can be afforded, and but very few cases of successful operations are on record.*

6. The anus and the continuous portion of the rectum are so contracted as scarcely to admit of any fluid discharge: we have even seen it scarcely pervious to air, so that on forcing in a grooved director, a considerable burst of flatus has escaped. This contraction may exist below, and yet the rectum be perfectly natural above. This contraction is sometimes not sufficiently noticed for several days or perhaps weeks after birth, because occasionally there is a small discharge of fæcal matter; it ultimately, however, excites attention from the great difficulty, straining, pain, and crying manifested at each evacuation. This condition of the parts sometimes admits of relief, by simple dilatation, by introducing a soft bougie, or some prepared sponge, which should be replaced after each evacuation, and secured, if possible, by adhesive plaster and a bandage. Should these means fail, an effectual cure may be obtained, as we have seen, by a division of the circumference. This may be done by introducing into the rectum a button-pointed bistoury for about an inch on a director, and dividing the wall of the intestine transversely, towards the ischium, first on one side, and then on the other, to the depth of about one quarter of an inch. The part must be carefully dressed, and the edges of each wound kept separate by lint. The success of the operation greatly depends on the care in the after treatment, particularly in renewing the dressing whenever it has been displaced.

The anus is occasionally found much contracted in new-born children who are contaminated by syphilis, and may be mistaken for a congenital malformation, especially of the kind last noticed, though not one in the strict sense of the expression; yet as it generally occurs at birth, it deserves the consideration of the practitioner in midwifery, whose attention is often first called to it by the same symptoms that attend the congenital malformation of this opening, namely, pain, difficulty, and straining at each evacuation, and a peculiarly small aperture. On examination, however, there are other appearances which will assist in explaining the real nature of the case, such as brown or dark discolouration of the surrounding parts, also considerable moisture, frequently excoriation, and even superficial ulceration in the adjacent structures. Small fissures in the anus, also, are observable, discharging tenacious matter. Similar appearances may exist about the commissures of the lips; some soft granulations or condylomata are also often present in the immediate vicinity of the anus; these frequently extend into the canal for a very little way. Other constitutional symptoms also are usually present, such as copper-coloured blotches on the skin, a tendency to cracking and excoriation of the skin about the hands and feet, and buttocks, an imperfect development of, or a tendency to a separation of the nails, general emaciation, suspicious appearances about the mouth and tongue, and a remarkable and peculiar hoarseness in crying. Many, if not most of these symptoms, aided sometimes by the history of the parents, will lead the practitioner to distinguish this contraction of the anus from the congenital malformation before described. The distinction is important, as the treatment in both is totally different; the syphilitic contraction invariably yields to gentle courses of mercury, administered in such form and dose as the circumstance of the case shall denote to be necessary. The local complaint disappears as the constitution is restored to health. Soothing, emollient applications are the best topical remedies; should there be any ulceration or excoriation about the part, the surface should be slightly stimulated daily, either by caustic or by the ordinary mercurial lotions.

Morbid conditions.—The anus is the seat of several morbid affections, some of which proceed from a specific cause; others are merely local. The *specific* diseases are syphilis and cancer; and the most common *local* derangements to which the anus is subject are, superficial ulcerations, excoriations, fissures, with or without contraction of the orifice from excessive irritability of the sphincter muscle, prolapsus ani, hæmorrhoids, fistula in ano, polypi, &c. Some of these last mentioned affections must, strictly speaking, be considered as appertaining to the rectum, under which head the reader will find them noticed. As, however, the anus is more or less engaged in these diseases, we shall make some observations on each. The anus is also subject to laceration in parturition, and from other causes.

Syphilis affects the anus at all ages; its appearances in the infant have been already noticed. In the adult it may present the primary venereal ulcer, which will have the same character here as elsewhere, only somewhat modified by the position and function of the part. The primary ulcer may be produced either by the direct application of the virus, or by extension of ulceration from the neighbouring organs, as not unfrequently occurs in the female. When the chancre is confined to the anus, which is very seldom the case, it may be difficult to discriminate between it and ulcera-

* See some observations by Petit, Mem. de l'Acad. de Chirurg. t. i. p. 378.

tions from other causes. Ulcers in this region are very generally difficult and slow to heal, owing to the irritation to which they are exposed from the passage of the fæces, and from the motion, pressure, and changes of form to which the parts are necessarily subject. Syphilis frequently appears here in the form of fissures, clefts, rhagades: these are very distinct, and different from the fissures attending the irritable anus. The syphilitic fissure is chiefly in the integuments; it seldom extends to any distance within the anus: the edges are somewhat elevated and thickened, and the surface secretes an adhesive pus, which forms crusts or scabs. Although in some instances these fissures or rhagades are attended with pain in defæcation, yet we have met many cases in which they caused very little uneasiness, and thus contrasted remarkably with the simple or the irritable fissure. Warts, condylomata, or excrescences about the anus are also frequent effects of syphilis in this region. These are generally on the cutaneous side of the anus, and very rarely, I believe, extend within it: they are not, therefore, difficult to distinguish from those vascular excrescences which are of mucous origin, and which so commonly protrude at the anus. Syphilitic warts and condylomata have generally a broad base; their surface is flattened by pressure against the opposite nates, soft and moistened with an offensive sero-purulent fluid. In these cases the surrounding skin is often excoriated, and clefts and superficial ulcers frequently exist in the vicinity of the anus.

Cancer is a disease to which the rectum is very liable, and may attack any part of the intestine, but usually exists at some inches above the anus. This opening, however, may become implicated by the extension of the disease. We occasionally see that form of cutaneous cancer called "*cancer scroti*" extend along the perinæum and involve the circumference of the anus. Its parietes may, however, be primarily affected by cancer, in which case the disease will commence by a chap or fissure, or more frequently by a tubercle, which, gradually increasing in size and in breadth, at length ulcerates and shoots out a cauliflower mass of granulations which protrude through the opening, causing great uneasiness, pain, and difficulty in defæcation: the surrounding parts in time become involved, ulceration extends, and a bleeding surface, very unhealthy, sloughy in some parts, and fungoid in others, discharging sanious and unhealthy matter, is an almost incessant source of pain and irritation, which in time wastes the health and strength of the patient. As no local application or constitutional treatment has yet been able to arrest this disease, it has been proposed to extirpate the anus and the lower end of the rectum when in this condition. Unfavourable as this operation may appear, and rarely as it has been undertaken in this country, it has been frequently performed in France, and with some success.*

* See Velpeau, Med. Oper. t. iii. p. 1033.

The anus is often affected with *warty excrescences*, which by a superficial observer might be condemned as cancerous, yet these are not of a malignant character, and may be cured by local remedies and due attention to the general health. I have seen a warty tubercular appearance about the anus, extending through it, and even involving the mucous surface for some height, and contracting the orifice so much as to cause great pain and difficulty in defæcation, and also materially impairing the general health by continual irritation; yet this state of parts is not malignant, nor is it prone to ulceration. Attention to the constitution, to the functions of the bowels, with local applications, will effect a cure. The anus is also frequently affected, and even inconvenienced by the growth of common warts; these, however, can be speedily removed either by the scissors or by caustic.

Excrescences frequently protrude through the anal opening, which are not warty or cutaneous growths, but elongations of the mucous membrane from a little distance above the anus. The anatomical disposition of these parts, before alluded to, together with a very relaxed state of the mucous membrane, accounts for the frequency of this occurrence. In some these protrusions only appear during defæcation, in others they are permanent, but much increased in volume during that act; and, indeed, in some they are so large and fill up so much of the canal, that they must be extruded before the fæces can escape. These excrescences are soft, and very vascular; they often appear without any assignable cause, though frequently they are attributed to hæmorrhoids, to constipation of the bowels, to violent straining efforts in defæcation, to fistula, or to long-continued irritation from any cause.

Prolapsus ani, or procidentia ani, although a term in somewhat common use, is rather an incorrect one, as the anus itself is too well maintained in its situation to descend, at least to any appreciable distance; the term rather implies a protrusion of a considerable portion of the relaxed mucous membrane of the rectum, or a portion of the large intestine itself, which must have become "invaginated or introsuscepted," and then protruded through the anus; in these conditions the anus is rather dilated, the mucous membrane sometimes remains protruded after defæcation, but in others it returns after this process, or it can be returned by the gentle pressure of the hand: this is not uncommon in children and in elderly persons. This disease has been ascribed to a relaxation of the sphincter; a circumstance which, however, does not seem to be proved, for in paraplegia and in paralysis of the sphincter, we do not find that the membrane protrudes, although the anus is often in these cases very dilatable; the condition referred to ought perhaps rather to be considered as one of the effects, than as the cause of the disease; moreover in some other instances the sphincter appears rather irritable, and painfully and dangerously constricts the protruded mass, which must then, in order to save the intestine from gangrene, be reduced by pressure properly applied, and by attention to posture. In the procidentia of old persons, Mr. Hey conceives that the relaxed state of the lower part of the intestine and of its surrounding cellular tissue, are in fault, and that hence the folds or excrescences about the anus remain, even when the parts have been returned; he therefore suggests the removal of these flaps from the circumference of the opening, and relates some well-marked cases in support of this practice, in which the operation had been successfully performed.

The *margin* of the anus, like that of the mouth, is subject to *fissures*, chaps, and superficial excoriations, sometimes caused by laceration induced by the passage of large and hardened fæces, but sometimes arising spontaneously, and sometimes connected with a peculiarly irritable and contractile condition of the sphincter ani. This disease must not be confounded with hæmorrhoids; on examination it is not easily seen, but little is apparent, the anus is much contracted, the orifice somewhat redder than natural, slightly tender on pressure, but exquisitely so on dilating it by introducing the finger; this must be done cautiously and slowly, a cleft will then be observed just where the skin and mucous membrane join, generally on one side extending a little way, from half an inch to an inch and a half, longitudinally up the intestine; on dilating the part still more, the surface of the fissure will be seen slightly ulcerated, and when touched it is exquisitely painful; the surrounding muscle is in a state of rigid contraction. It is doubtful whether the contraction is the cause of the fissure, or whether the latter is the cause of the irritable and contracted condition of the muscle. Both explanations may be occasionally correct; but it is most probable that the irritable state of the muscle induces the ulcerated fissure, inasmuch as this muscular contraction occasionally exists without any fissure, and is then equally painful; and fissures frequently exist, as in syphilis, without inducing any spasmodic constriction of the muscle, and accordingly are attended with little or no pain.

Contraction of the anus also frequently exists without any fissure; sometimes it is congenital, sometimes it appears in the adult; the pain and other symptoms are nearly analogous, and as severe as in the case of fissure; the examination by the finger however does not detect one part to be more painful than another, as is the case in that disease; and this is almost the only symptom distinguishing these two affections.

The term *hæmorrhoid* has been applied by writers, practitioners, and invalids to any condition of the rectum and anus in which a discharge of blood takes place. It is, however, more correctly applied to the small tumours which are frequently seen at and very close to the inner border of the anus or even occupying the very aperture, also to somewhat similar productions situated within the rectum, at the distance of one, two, or even three inches above the anus. From such tumours occupying these different positions, they have been arranged by all writers into *external* and *internal* hæmorrhoids; the latter are very important and demand the close attention of the surgeon, both as to their pathology and symptoms, as being frequently obscure and liable to be mistaken not merely for the ordinary diseases of the anus, such as fissure, blind internal fistula, &c., but also to be confounded with a varicose condition of the veins of the rectum, which is by no means an uncommon condition, or with those vascular tumours which are productions of the mucous membrane occasionally protruding at the anus, that have been already noticed, and are of a wholly different character from true hæmorrhoidal tumours, or with the protrusions of the mucous membrane itself, the effect of the relaxation of its cellular connections. As the full consideration of this important branch of pathology belongs to the article on the morbid anatomy of the rectum, we shall here confine ourselves to a few observations on external hæmorrhoids and analogous tumours.

External hæmorrhoids appear at the border of the anus as small bluish tumours, the colour however varying according to the condition of the tumours, being sometimes of a dark and deep red or black, at others pale and almost white; in size they vary from a grain of small shot to a large cherry; they are sometimes full and almost bursting, at others they are soft like a flaccid nipple, empty or withered; they are covered on the anal side by the delicate cuticle which is smooth and glossy, and on the outer side by the common integument; when small, they are moveable and can be distinctly felt to be in the subcutaneous cellular tissue; when large and tense, they appear more connected with the skin itself; an attentive examination can always distinguish between these and the several excrescences, vegetations, or condylomata, which have been already mentioned as the effects of syphilis, as also the folds or crests of integument and mucous membrane which are found so frequently prolonged from the border of the anus. These tumours remain in many persons for years free from pain, and productive of little, if of any, inconvenience; occasionally, however, and periodically in some, they enlarge, inflame, and interfere with the functions of the anus, and by sympathy engage the adjacent organs, and are relieved either by a copious discharge of blood, or by suppuration, or by the interference of art.

The liability of the veins immediately about the anus to varicose enlargement appears in some measure founded in anatomical structure. If we inject the intestinal veins in the adult with wax injection, we shall often find a little above the anus, just where the skin and mucous membrane unite, a sort of constriction on the vessels; the veins appear larger immediately above it, and again below it, and many of the branches in the venous plexus around the anus appear to be enlarged, while in the very spot or circular line alluded to, the vessels appear to be compressed. It may occur, then, that hardened fæces impacted in the rectal pouch, which is above this point, may assist in obstructing the more free flow of blood, and thus encourage the enlargement of these anal veins, and the same effect may be still further induced by the muscular pressure employed in defæcation; in support of this view we find that children are almost free from this varicose condition of these veins, unless under peculiar circumstances; and in the adult it usually occurs in those of constipated habit of bowels; it is also relieved or removed by attention to their functions. The true hæmorrhoidal tumours, external as well as internal, must be regarded as essentially different from a varicose condition of the anal veins, although they are often connected with the latter, and it must be admitted that in some cases they may owe their origin in a great measure to venous dilatation. Varices of the anal veins are simple dilatations either of a trunk or of some of the branches of these vessels; their cavity is continuous with that of the vein, and freely communicates with it, and pressure on the varix empties it of its contents; its tunics are the venous coats and the membrane of the intestine; whereas hæmorrhoidal tumours are wholly distinct from the veins, and are either simple cysts, lined by a smooth membrane, or they are composed of a spongy cellular texture, not unlike the erectile tissue. This latter is usually the condition of recently formed hæmorrhoids, whereas in those of long standing the single or divided cyst is the ordinary structure; this cyst will be found to contain a little blood, partly fluid and partly coagulated; and when the internal surface is minutely examined, one or more fine pores will be visible, the orifices of capillary vessels, through which warm water, if steadily injected by the inferior mesenteric artery, will exude on the surface. In the cellular or more recent hæmorrhoids the texture appears very vascular, soft, and spongy, as also the surface of the tumour, from which blood or serum will sometimes exude during life. These cellular hæmorrhoids in time become circumscribed, the cellular texture becomes more or less perfectly absorbed, and the cyst-like structure becomes more developed; however a very recently formed hæmorrhoid may, and sometimes does, present a distinct cyst or cavity, as may be readily conceived when we consider the process whereby these tumours come to be developed, which, as far as our observation extends, is as follows: from continued irritation from any exciting cause, such as disease of the intestine or anus, worms, or from a local plethoric condition, spontaneous, as far as we can know, the capillary circulation is increased in the loose submucous tissue in this region, a small quantity of blood, or lymph, or serum, is effused into it, perhaps from the rupture of some small vessels, or exhaled from their dilated extremities. A slight degree of inflammation attends this condition: the part affected, that is, the cellular tissue, becomes more highly organized, thickened, vascular, and spongy. After some time, this increased vascular action subsides, and in process of time the whole may nearly disappear, but in general a part of this more highly organized spongy tissue remains, it being fully supplied with nourishment; the absorbents in due course modify its appearance; the surrounding thickening is removed, as also some portion of the cellular mass, and thus the formation of the hæmorrhoidal cyst is completed. A structure like this, connected with the capillary system, must be influenced by the same causes as can affect the latter; thus irritation local or general, mechanical injury, or general or local plethora are all capable of exciting increased action in it, and of inducing all those symptoms and changes which are so well known to attend during hæmorrhoidal inflammation.

Fistula in ano is a disease of such very frequent occurrence, and so well understood and described by every surgical writer, that it is scarcely necessary to do more than allude to it in this place: strictly speaking it is not a disease of the anus, as that opening is in general totally unaffected, except as regards its functions: it should rather be regarded as a disease of the anal region. There is one form of fistula in ano, however, which is seated on the very confines of this opening; it is troublesome and distressing, attended with heat, itching, and excoriation, pain during defæcation, and constant purulent or sero-purulent discharge: without due attention it may be overlooked by the surgeon, as the orifice is so close to the anus as to be concealed by the natural rugæ, and so small as only to admit a lachrymal probe; the sinus is not more than an inch or half an inch long; its internal opening is on the very edge of the anus, the whole is immediately under the skin, and does not involve any other structure; it is not preceded by regular abscess, neither does it or the treatment necessary for its cure involve the sphincter or any other structure, except the fine integuments; it most probably originates in irritation of some of the anal sebaceous follicles, and sometimes two or three of such fistulæ may exist at the same time.

The true or deep fistula in ano has its origin in deep-seated abscess commencing close to the rectum, or in the centre of the ischio-rectal space of either side: when in the former, some mechanical irritant or some disease of the intestine may have been the cause or origin of the abscess; when in the latter, it often arises without any obvious reason, but frequently appears to have been connected with some peculiar delicate or morbid condition of the constitution. All abscesses in this situation do not necessarily end in fistula; if they have been small, superficial, opened early, and treated judiciously, they may be healed as perfectly as abscesses in any other situation; but when deap-seated, of slow growth, and long continuance, and when depending on some deep-seated mechanical irritant or on constitutional causes, then the abscess usually attains considerable size, and having opened either into the rectum or through the integuments, or in both these directions, it continues to secrete and to discharge a considerable quantity, and shews no disposition to alter its action or to heal. We have already detailed all the local peculiarities of the ischio-rectal region (the seat of this abscess) which can satisfactorily explain the difficulty or the impossibility of keeping at rest or retaining in apposition the sides of the cavity, a condition almost essential to the healing of an abscess in any situation, and hence the necessity of surgical interference. Abscess in this region frequently originates close to the rectum in consequence of irritation and ulceration in this intestine; this irritation may be caused by disease, such as cancer or stricture of the rectum, or by some foreign body becoming impacted in one of the lacunæ. Above the sphincter is the rectal pouch, and an irregularly shaped or sharp substance, such as a pin, a fish-bone, or one of the small bones of a fowl, &c. brought into this in the fœcal mass, may catch in its villous or rugous surface, the muscular powers of the intestine are excited by this irritation to increased and repeated efforts of expulsion; these only serve to impact more closely the foreign body in the parietes of the intestine; the submucous tissue, which may now contain the whole or part of this substance, becomes inflamed, suppuration follows, an abscess is formed close to the intestine; in some time the matter is discharged either through the rectum and anus, or coming to the surface of the nates it receives exit by puncture. In this case of abscess, which we suppose to have been caused by a foreign body impacted in the intestine, the matter is usually discharged by the rectum, at least at first, although this exit will not always prevent it still tending towards the cutaneous surface: in cases of fistula, however, arising from such a cause, we are most likely to meet with the *blind internal fistula*, at least in the early period; whereas, when abscess forms spontaneously in this region, and opens on the surface, the intestine is often at first and for some time wholly disengaged from the disease, even after the abscess has opened, notwithstanding which it is productive of great inconvenience and more or less of pain during defæcation; in this state, when the fistula or abscess remains discharging through the skin only, it constitutes what is termed a *blind external fistula;* by degrees the rectum becomes denuded, and ultimately ulceration opens it by one, and sometimes, but rarely, by more orifices; this opening is usually about half an inch above the edge of the anus, and between the two sphincters. I have observed it to hold this situation in a great number of cases, which I have examined both in the living and the dead; in a few instances, however, I have found it opening at a higher point. When the abscess arises from irritation in the rectum, then I have observed the internal opening to be higher, that is, in the dilated pouch of the rectum, which during life will appear to be from an inch and a half to two inches from the anus; but when the abscess has commenced spontaneously in the anal adeps, and opened on the surface first, I have then in general found the rectal opening less than an inch distant from the anal orifice, and in a groove or recess between the two sphincters. When the abscess discharges by two openings, that is, through the skin and through the rectum, a *perfect* or *complete fistula* is then said to exist.

Fistulæ occasionally appear in the anal region which have their source at a much greater distance; thus, any diseases of the uterus or vagina in the female, of the prostate or urethra in the male, which end in suppuration, may cause collections of pus which will burrow under the fasciæ and skin to the vicinity of the anus, and open near it or even into the rectum. Psoas and lumbar abscesses also may descend into the pelvis and approach the surface, either in front or at one side of the anus. In morbus coxæ also chronic abscesses which form about the nates not unfrequently open in the same situation.

Polypus is seldom a disease of the anus; it most usually grows from the rectum, and protrudes occasionally only at the anus.

(Robert Harrison.)

For the Bibliography of this article see that of Intestinal Canal.

AORTA* (human anatomy). —(*Arteria magna.* Fr. *aorte.* Germ. *Aorta, die grosse Schlagader.* Gr. αοϱτὴ.) Hippocrates applied the term αοϱται to the lower part of the bronchi. Aristotle called the great trunk of the arterial system φλεψ αοϱτὴ.

The aorta, one of the two great arteries which spring from the heart, is the trunk of the arterial system of the general circulation; it arises from the extreme right part of the base of the left ventricle of the heart, which, from this circumstance, is sometimes called the aortic ventricle. There is a ring of tendinous structure surrounding the aortic opening of the ventricle, which in the stag and some others of the ruminantia is more or less partially ossified; into this ring the muscular fibres of the heart are inserted. The middle tunic of the aorta is divided at its commencement into three semicircular flaps by an equal number of angular notches, forming thus a festooned edge which is bordered throughout its whole extent by a marginal tendinous cord. These three semicircular flaps touch the aortic opening of

* The etymology of this term is by no means clear. The following extract from Spigelius (de corp. hum. fabrica) gives a not improbable origin for it.—"Veteribus Græcis αορτην dictam fuisse vaginam cultrorum Macedonibus familiarem, quorum manubrium nonnihil incurvatum erat, ad quam sane figuram quam proxime accedere videtur arteriæ magnæ truncus, quâ parte ex corde originem suam ducit." Cloquet suggests the theme, αορτεομαι, suspendor, "parceque l'aorte considerée dans sa totalité parait comme suspendue au cœur." Aristotle, by whom the term seems to have been first employed, generally denominated it φλεψ ελαττων, in reference to the vena cava, which he considered the greater vein.—R. B. T.

the ventricle at three equidistant points by the centres of their convex edges, where the fibres of their marginal cord become intimately blended with those of the tendinous ring of the aortic opening of the ventricle; between these points are three triangular intervals, each of which is occupied by a thin tendinous expansion of considerable strength, having one of its sides continuous with the tendon which encircles the aortic opening of the ventricle, and the other two continuous with the marginal tendinous cord of the festooned commencement of the middle tunic of the aorta.

The convex margins of the sigmoid valves of the aorta are attached to the margins of the semilunar flaps, and are composed of thin expansions sent off from their marginal tendinous cord, covered by a reflexion of the lining membrane common to the heart and arteries. Hence it follows that the fibres of the middle tunic of the aorta are not continuous with the muscular fibres of the ventricle, being separated from them by the tendinous structure above described; this tendinous connexion is strengthened and supported externally by a layer of dense cellular membrane, which may be regarded as the commencement of the cellular or external tunic of the arterial system. The lining membrane of the heart, after being reflected over the sigmoid valves, extends itself into the aorta, and becomes continuous with the lining membrane of that vessel. The muscular substance of the heart rises in form of a swollen annular border around the commencement of the aorta for a little distance, and is connected to it by dense cellular membrane. The serous layer of the pericardium passes loosely from the surface of the heart over the aorta; a quantity of soft adipose substance, which is absent in the fœtus during the earlier months, begins to collect under the serous membrane in this situation, sometimes before, sometimes after birth, and, increasing as life advances, is found in considerable quantity in old age. The foregoing description of the connexion of the aorta with the heart has been determined by my own dissections repeatedly performed, and agrees, in its leading particulars, with the account given of it by M. Beclard.*

The aorta, arising from the left ventricle of the heart opposite the left side of the body of the fourth thoracic vertebra, ascends at first obliquely forwards, and to the right behind the middle bone of the sternum, until it arrives at the right side opposite the second intercostal space, and behind the sternal articulation of the cartilage of the second rib; it then stretches backwards and to the left, opposite the junction of the upper and middle portions of the sternum, on a level with the body of the second thoracic vertebra, and curving downwards it reaches the left side of the body of the third thoracic vertebra, on which there is a slight depression for lodging it; from this point it descends through the posterior mediastinum, advancing in its course downwards from the left side to the front of the bodies of the vertebræ; it passes through the aortic opening of the diaphragm, enters the abdomen, and on the body of the fourth abdominal vertebra gives off the two primitive iliac arteries, in which it seems at first view to terminate; the aorta, however, does not end here, but is continued, although greatly reduced in size, under the name of the middle sacral artery, as far as the extremity of the os coccygis.

The aorta is usually divided by anatomists into three portions; the curved portion from the heart to the third thoracic vertebra is called the *Arch* of the aorta; the remaining portion of the vessel, to which the name of descending aorta has been sometimes given, is called *Thoracic* aorta above the diaphragm, and *Abdominal* aorta below that muscle.

The *Arch* of the aorta is divided into three portions, for the purpose of describing its numerous important relations to surrounding parts with greater accuracy; these are, first, the ascending or anterior limb; second, the transverse portion; and, thirdly, the descending or posterior limb. The commencement of the aorta is covered anteriorly and to the left by the pulmonary artery, on the right by the right auricular appendage, the tip of which overlaps it in front, and behind it rests on the sinus of the left auricle. The ascending limb of the arch lies first in front of the right pulmonary artery, as that vessel crosses behind it in its course to the right lung, and then it gets in front of the right bronchus, and the cluster of bronchial glands which fill up the angle formed by the bifurcation of the trachea; it is bounded on the right side by the superior vena cava, and on the left by the pulmonary artery; anteriorly it is separated from the sternum by the anterior margins of both lungs, which here approximate, and by the narrowest part of the anterior mediastinum, where the attached surfaces of the opposite pleuræ touch. This portion of the aorta is contained within the bag of the pericardium, the serous layer of which invests it in every part except where it lies in contact with the pulmonary artery.

The transverse portion of the arch is shorter than the ascending limb. The three great arteries of the head and upper extremities arise from its superior sides; inferiorly it rests on the left bronchial tube; in front it has the cellular membrane of the anterior mediastinum, the thymus gland, and the inferior part of the vena innominata; behind it rests on the trachea a little above its bifurcation, and on the left recurrent nerve. The posterior limb is the shortest portion of the arch; it lies immediately behind the division of the pulmonary artery, which is connected to it by a ligament, the remains of the ductus arteriosus; and it is crossed by the left par vagum; on the right side it is in contact with the œsophagus, thoracic duct, and left side of the body of the third thoracic vertebra; the rest of the circumference of the thoracic aorta is covered by the left pleura, and is in contact with the internal surface of the left lung. In the generality of adults having

* Dict. de Médecine, art. Aorte. Elemens d'Anat. Générale, par Beclard. Paris, 1823.

the chest well formed, and the heart and the arch of the aorta free from disease, the origin of the aorta is opposite the sternal articulation of the cartilage of the fourth rib of the left side in the male, and the intercostal space above it in the female; the ascending limb of the arch, which is behind the middle bone of the sternum in the greater part of its length, may be felt pulsating on the right side of the sternum in the second intercostal space; the highest part of the transverse portion of the arch is on a plane with the centre of the sternal extremities of the first pair of ribs, and about an inch below the upper margin of the sternum: the arch of the aorta terminates opposite the lower edge of the cartilage of the second rib of the left side.

The *thoracic aorta* descends in the posterior mediastinum, and advances from the left side to the front of the thoracic portion of the spine, crossing in its course the left intercostal veins, and the left vena azygos when that vein exists; in front it is covered by the left bronchus, the posterior surface of the pericardium, the lower extremity of the œsophagus, and the left stomachic cord of the par vagum; on the right side it is bounded by the œsophagus, thoracic duct, and vena azygos; on the left side it is covered by the pleura, and in contact with the internal surface of the left lung, and at its lower extremity the left splanchnic nerve comes into contact with it, and most frequently accompanies it through the diaphragm.

The *abdominal aorta*, which enters the abdomen between the crura of the diaphragm, descends along the front of the abdominal vertebræ and the left lumbar veins; it is covered in front by the solar plexus of nerves, the stomach, pancreas, transverse portion of the duodenum, the splenic and left renal veins, the small intestine, and the root of the mesentery; on the right side it is bounded by the abdominal vena cava, and the commencement of the thoracic duct, and on the left it is covered by the peritoneum going to form the left layer of the mesentery. The termination of the aorta in the common iliacs and the middle sacral arteries is a little below the level of the umbilicus.

A remarkable deviation from the cylindrical form, which is one of the general characteristics of the arterial system, is observable in two parts of the arch of the aorta; the first of these occurs at the commencement of this vessel in form of three dilatations corresponding to the semilunar flaps already described; they were first pointed out by Valsalva, and have received the name of the lesser sinuses of the aorta; they exist at all periods of life, and increase in size with years; the other deviation from the cylindrical form is a dilatation on the right side of the ascending limb of the arch at its junction with the transverse portion; this dilatation, which does not exist in the fœtus, grows larger as life advances, and appears to be produced by the impulse of the blood striking against this part of the aorta at each successive systole of the left ventricle. The aorta in the succeeding part of its course gradually grows smaller in a degree proportionate to the size of the branches it gives off.

The thickness of the aorta is proportionally less than that of its branches; it is thinner at its commencement than in the arch, in which part, according to Haller, it is thicker by an eighth on the convex than on the concave side; it gradually diminishes in thickness as it descends through the thorax and abdomen, but its power of resisting distention instead of being diminished in an equal degree was found by Wintringham to be greater at its lower part than near the heart.*

The structure of the aorta is the same as that of the rest of the arterial system in general; its external tunic, however, is slighter than that of all other arteries except those of the brain, it is weaker the nearer it is examined to the origin of the aorta; it is strengthened near the heart by the covering which the serous layer of the pericardium gives to the aorta, and by an expansion from the fibrous layer of that membrane, which is lost on the transverse portion of the arch. The cellular sheath of the aorta in which the soft fat around its origin is deposited, becomes so fine where the vessel is passing out of the pericardium as to lead some anatomists to deny its existence in this situation; it becomes more evident in the course of the descending aorta through the mediastinum, and is still more considerable around the abdominal aorta, where it is usually loaded with a considerable quantity of adipose substance.

The branches which arise immediately from the aorta may be divided into orders, according to the degree of remoteness or the relative size and importance of the parts which they supply with blood; first, the branches which convey blood to the two extremities of the trunk and the limbs attached to them; these arteries, which are of considerable size, are the *arteria innominata*, the *leftc arotid* and *left subclavian*, which, arising from the transverse portion of the arch, are distributed to the head, neck, and upper extremities, and the *primitive iliac arteries* which arise from the lower part of the abdominal aorta supplying the pelvis and the lower extremities. 2nd order.—Branches somewhat smaller going to the thoracic and abdominal viscera and the parietes of the chest and abdomen; the coronary arteries which supply the heart arise from the aorta immediately after its origin; the bronchial arteries which supply the substance of the lungs, and the intercostal arteries supplying the parietes of the chest arise from the thoracic aorta; the cœliac, superior and inferior mesenteric, which supply the digestive organs; the renal arteries which supply the kidnies; the spermatic going to the organs of generation, the inferior phrenic supplying the diaphragm, and the lumbar arteries going to the parietes of the abdomen and lumbar region of the spine, are the vessels of this order which arise from the abdominal portion of the aorta. 3rd order.—Branches of much smaller size are sent from the aorta to se-

* Experimental Inquiry on some parts of the Animal Structure. London, 1740.

condary parts which lie in its vicinity, as the thymus, the pericardium, the œsophagus, the renal capsules, ureters, &c. 4th order.—Small arterial twigs lost in the neighbouring cellular substance, lymphatic glands, and in the coats of the aorta itself.

Development. — The aorta appears to be formed in the fœtus prior to the heart and subsequently to the system of the vena porta, with which, according to Baer, Rathke, and Meckel, it is connected by a small dilatation described by Dr. Allen Thomson* as a curved tube, which is the rudiment of the heart. (See Ovum.) Whilst the heart has but a single ventricle, the aorta and the pulmonary artery form a common trunk, which afterwards becomes divided by the dedelopment of the contiguous portions of the circumference of both vessels; during the remaining periods of intra-uterine life, and for a short time after birth, the pulmonary artery communicates with the aorta by the ductus arteriosus, which appears as a continuation of the trunk of the pulmonary artery opening into the concavity of the arch of the aorta at its termination. The ductus arteriosus becomes impervious soon after birth, and having undergone a process of complete obliteration, is finally concerted into a ligamentous cord. The size of the arch of the aorta is less in proportion in the fœtus than in the adult, whilst the thoracic aorta is larger, being increased in size below the ductus arteriosus. The arch lies closer to the spine in the fœtus in consequence of the trachea and bronchi behind it being so much less developed than in the adult, and the thymus which is between it and the sternum being so much larger during fœtal life. In old age the curvature of the arch of the aorta is much greater in consequence of the great sinus having increased considerably in size.

Anomalies.—The aorta presents occasional varieties or anomalies in the mode of its origin, its course, termination, and the number and situation of its branches. It is an interesting fact, that almost every irregularity hitherto observed in the course and branching of the aorta in the human subject, represents the disposition which that vessel constantly exhibits in some of the inferior animals. The anomaly of the aorta arising from both ventricles, and causing that condition called cyanosis, will be more properly considered in the article Heart. The following anomalies of the course of the aorta have been recorded by anatomists:—

1st. The aorta sometimes divides immediately after its origin into a right and left trunk, which, after having each given off the arteries of one side of the head and one upper extremity, join to form the descending aorta. Malacarne† has described a remarkable case of this anomaly; the aorta was of an oval form at its origin, its greater diameter being to its lesser in the proportion of three to two, it had five sigmoid valves in its interior, it divided immediately after its origin into a right and left trunk, from each of which arose a subclavian, an external and an internal carotid: after the two trunks had run for a space of four inches distinct, they joined to form the descending aorta. Hommel, a Norwegian anatomist,* relates a case in which the transverse portion of the arch of the aorta divided into two trunks, one of which passed before and the other behind the trachea, after which they joined to form the descending aorta, having encircled the trachea with a sort of ring: this anomalous division of the arch of the aorta is the more remarkable as it approaches the condition of the vessel which is constant in all known reptiles. 2d. The arch of the aorta is sometimes absent, in consequence of the vessel dividing, immediately after its origin, into two great trunks, one of which gives off the arteries of the head and upper extremities, whilst the other becomes the descending aorta.† This distribution is similar to that in the horse, rhinoceros, and other pachydermata, in the ruminantia, and some of the rodentia. 3rd. Varieties in the course of the arch sometimes, although rarely, occur, as, for instance, when the arch of the aorta, instead of crossing to the left in the usual manner, curves over the right bronchus, and gets to the right side of the spine, whence it either immediately crosses behind the trachea and œsophagus to the left, or continues its course along the right side of the spine to the lower part of the thorax; in cases of complete transposition of the viscera, where the heart is in the right side of the chest, the arch of the aorta is also reversed, in which case its thoracic portion descends along the right side of the spine.‡ Instances are recorded in which the descending aorta, a little below its arch, was very much contracted in its area or even completely obliterated for a certain distance, below which it resumed its full size: the circulation in these cases was carried on by the anastomosing of large collateral branches arising above and below the constricted or obliterated part.§

Anomalies of the branches of the aorta are more frequent: according to Meckel the branches arising from the arch deviate from the normal condition in one person out of every eight.|| The branches arising from the arch of the aorta present three kinds of anomaly, which, as to their frequency, occur in the following order: 1st, an increase in their number; 2d, a diminution; and 3d, an anomaly in the identity or order of the branches arising from this part without any increase or diminution of their number. In anomalies of the first

* Vide Edinburgh New Philosophical Journal, by Dr. Jameson, for October, 1830.

† Osservazioni in Chirurgia. Torino, 1784.

* Comm. Noric. ann. 1737.

† Vide Abhandlungen des Josephinischen Medicinisch-Chirurgischen Akademie. Band, i. S. 271. Taf. 6. Wien. 1787.

‡ Meckel Handbuch der Menschlichen Anatomie. Band iii. Halle and Berlin, 1817. Abernethy in Phil. Trans. 1793.

§ Desault in Journal de Chirurgie, tom. ii. Dr. Goodison in Dublin Hosp. Reports. Brasdor Recueil Periodique de la Société de Médecine. Paris, tom. iii.

|| Handbuch der Menschlichen Anatomie. Band iii. Halle and Berlin, 1817.

kind, the number of branches is most frequently increased to four, by the left vertebral arising from the arch between the left carotid and left subclavian, as in the phoca vitulina; next to this in frequency is the instance of the inferior thyroid arising from the arch between the innominata and left carotid, then the internal mammary, and, lastly, the most unusual is the thymic artery: it is more unusual to find the number of branches coming from the arch increased to four, in consequence of the innominata being absent, the right carotid and right subclavian arising separately; in such a distribution the right subclavian most frequently arises from the left extremity of the arch after the left subclavian; it may, however, be the first branch of the arch to the right, or it may arise between the two carotids, or, as more rarely happens, between the left carotid and left subclavian. The number of branches arising from the arch will be increased to five or upwards, when two or more of the above-mentioned anomalous branches arise from it at the same time. Of the second kind of anomaly, or that by diminution of the number of branches, the most frequent is where these are reduced to two, of which there occur the following varieties: *a*. the innominata sometimes gives off the left carotid as an additional branch, and the left subclavian arises separately, as in many quadrumana, several of the carnivora, as the lion, cat, dog, weazel, several rodentia, &c.; *b*. sometimes there are two arteriæ innominatæ, each dividing in a symmetrical manner into the subclavian and carotid of its own side, as in cheiroptera and the dolphin; *c*. sometimes when the arch gives off but two trunks, one of them divides into the two carotids, and the other into the subclavians; *d*. the right subclavian may arise distinct, and a common trunk give off the two carotids and left subclavian; the origin of a single trunk from the arch of the aorta supplying the arteries of the head and upper extremities is equivalent to a division of the aorta into an ascending and descending trunk, already noticed. The third kind of anomaly partakes of the characters of the two preceding, although the number of branches is the same as in the normal state: its varieties are, *a*, the left vertebral arising from the arch, whilst the left carotid comes from the innominata; *b*, the two carotids may arise from a common trunk between the origins of the right and left subclavians, as in the elephant; *c*, the right subclavian and right carotid may arise as distinct branches, whilst the left carotid and left subclavian come from a common trunk, forming a complete inversion of the usual order; *d*, the left carotid may arise from the innominata, whilst the right carotid comes from the part of the arch in the situation usually occupied by the origin of the left carotid. Anomalies of the branches of the descending aorta are less frequent; the following are among the more remarkable: *a*, the cœliac and diaphragmatic may arise above the diaphragm; one or both of the diaphragmatics may be given off by the cœliac; sometimes the cœliac and superior mesenteric arise by a common trunk as in the tortoise; sometimes there are two or more renal arteries on one or both sides, and sometimes the primitive iliacs are given off much higher than usual, in which case they are sometimes connected by a cross branch before they divide into the external and internal iliacs: it sometimes happens, when the iliacs are given off higher than usual, that the inferior mesenteric arises from the left of them.

The diseased conditions of the aorta are described in the articles Artery and Heart. The aorta, as Beclard remarks,* is more subject than any other artery to the ovoid dilatation in its ascending, and the lateral dilatation in its descending portion; it is also very subject to osseous or calcareous deposits, to fissures and ulcerations, to tubercles and small abscesses in its parietes, and to aneurism. Wounds of the aorta are constantly mortal. Laennec has observed a particular lesion of this vessel; it was a fissure of the internal and middle coats, from which the external tunic was extensively separated by a quantity of blood which had been effused between it and the middle tunic. The late Mr. Shekelton has described, in the Dublin Hospital Reports, a form of aneurism of the lower part of the abdominal aorta, in which the blood forced its way through the internal and middle coats, dissected the middle from the external for the space of four inches, and then burst into a lower part of the canal of the artery, forming a new channel which eventually superseded the old one, which the pressure of the tumour obliterated.

Granular excrescences are sometimes formed on the valves of the aorta, which Corvisart conjectured to be of venereal origin. The internal tunic of the aorta sometimes presents a red appearance, not peculiar, however, to this vessel, and occurring in certain forms of fever. Obliteration or constriction of the aorta is a condition rarely met with; its existence may be traced either to pressure on the vessel from without, morbid thickening of its coats, or the formation of coagula internally; this latter occurrence being most usually a consequence of the spontaneous cure of aneurism.

Aneurisms of the aorta produce various effects on surrounding parts; thus the heart, lungs, trachea, œsophagus, pulmonary artery, large veins, thoracic duct, and the various organs in the abdomen placed in their vicinity, may suffer derangement of their functions, displacement, atrophy or partial destruction, according to the degree of pressure to which they are subjected.

Aneurisms occurring in the ascending portion of the aorta, which is within the pericardium, are often attended during life by many symptoms very similar to those of disease of the heart itself, while their pressure may produce a diminution of the calibre of the pulmonary artery, obstruct the free passage of the blood through the vena cava superior, and even in-

* Dictionnaire de Médecine, art. Aorte.

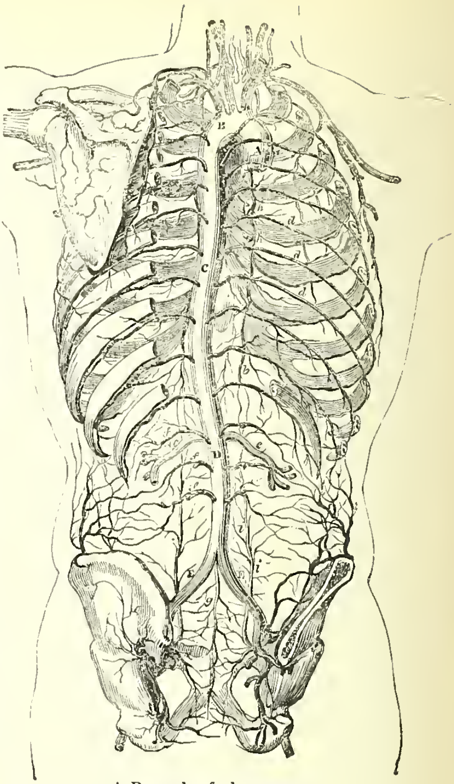
terfere with the full distension of the auricles. Aneurisms of the transverse portion of the aorta, when directed forwards, usually project at the right side of the sternum about the second intercostal space: when the sac extends upwards towards the neck, it frequently becomes a matter of extreme difficulty to distinguish an aneurism of the aorta from an aneurism of the innominata or some other large arterial trunk in the neighbourhood; cases are on record, where the pressure of such aneurisms of the aorta caused obliteration of the subclavian and common carotid. When aneurisms extend backwards, they produce a variety of effects, interfering with respiration and deglutition from their pressure on the trachea and œsophagus, sometimes producing obliteration of the thoracic duct. The pressure produced by aneurisms of the thoracic and abdominal aorta occasionally cause absorption of the bodies of the vertebræ, and give rise to an appearance not very dissimilar to that produced by caries.

Aneurisms of the arch of the aorta do not so often terminate fatally by making their way through the anterior parietes of the chest, and opening externally as by bursting internally: when they occur in that part of the arch of the aorta covered by the pericardium, they most usually burst into the sac of that membrane; cases are recorded in which aneurisms of the aorta have burst into the pulmonary artery,* or, taking a direction backwards, have opened into the trachea, œsophagus, or the substance of the lungs. Aneurisms of the thoracic portion of the aorta sometimes burst into the left pleura, sometimes into the posterior mediastinum: they have been known to point at the left side of the spine, after having caused absorption of the heads of the ribs and sides of the bodies of the vertebræ. In two cases observed by Laennec and Mr. Chandler, aneurism of the thoracic aorta burst into the spinal canal. Aneurisms of the abdominal aorta most usually burst into the cellular tissue of the lumbar regions behind the peritoneum, seldom into the sac of that membrane. An aneurism of the abdominal aorta has been observed to make its way backwards by the side of the spine, and point in such a situation as to have been at first mistaken for lumbar abscess.

Branches of the aorta. I. *Branches arising from the arch.*—From the arch of the aorta five branches are given off; two from its commencement, *the coronary arteries*, and three vessels of considerable size (*fig.* 78 *a b c*), from the upper part of its transverse portion to supply the head and the upper extremities. The coronary arteries of the heart or the *cardiac* arteries arise from the aorta close to its origin, and immediately above the free borders of the sigmoid valves; they are usually two in number, one for each ventricle.

The *right*, *anterior* or *inferior* coronary artery is often larger, seldom smaller than the

Fig. 78.



A B, arch of the aorta.
C, thoracic aorta.
D, abdominal aorta.
E, common iliac artery.
g, middle sacral artery.

left; it arises from the anterior side of the aorta above the anterior sigmoid valve, coming out from between the roots of the aorta and pulmonary artery, it passes downwards and to the right side in the groove between the right auricle and ventricle, turns round the right edge of the heart until it reaches the groove of the septum on the inferior surface of that organ, when it changes its direction, coursing along that groove until it arrives at the apex of the heart, where it anastomoses with the left coronary artery; in its course it gives off to the right and left many tortuous branches arising nearly at right angles, the right branches are smaller and go to the right auricle, the left are larger and belong to the right ventricle, which they traverse in a longitudinal direction towards its apex. From the origin of the right coronary artery two small branches are given off, one to the commencement of the pulmonary artery and the surrounding fat, which anastomoses behind the pulmonary artery with a branch of the left coronary; the second branch anastomoses with the bronchial arteries.

The *left posterior* or *superior* coronary artery arises between the left auricle and the posterior surface of the pulmonary artery, de-

* Dr. Wells in Trans. of a Society for Improvement of Medical and Surgical Knowledge, vol. iii.

scending to the left between the left auricle and pulmonary artery, and, having reached the groove at the base of the heart, dividing into two or three branches; one anterior longitudinal descends along the anterior groove of the septum to the apex of the heart, where it anastomoses with the termination of the right coronary artery, with which it holds frequent communication by branches which it sends over the anterior surface of the right ventricle, while it sends some large branches to the left ventricle; this branch at its commencement gives small twigs to the aorta and pulmonary artery. The second branch of the left coronary artery covered by the great coronary vein passes from right to left in the groove between the left auricle and ventricle, to both of which it gives many branches, turns round the left border of the heart, changes its direction, and descends by the side of the right coronary artery to the apex; the third branch sinks into the substance of the septum and continues its course to the apex; this branch sometimes arises directly from the aorta; in this latter case, of course, there will be three coronary arteries arising from the aorta; Meckel has once seen four; the supernumerary coronary artery does not arise above any particular valve, but usually close to the origin of one of the normal branches. It is rare to find but one coronary artery in the human subject, which corresponds, according to Camper, with the normal conformation in the elephant. The three large branches arising from the transverse portion of the arch of the aorta and sent to the head and upper extremities, will be described in a separate article.

II. *Branches of the thoracic aorta.*—These may be divided into *anterior* and *lateral.* The anterior branches are, the *bronchial, œsophageal,* and *posterior mediastinal.* The lateral are the *inferior* or *aortic intercostal* arteries. The *bronchial* arteries are usually two in number, one for each lung; sometimes, however, there are two for each lung, and sometimes the right and left bronchial arise from a common trunk, which usually springs from the first aortic intercostal of the right side.

The *right* bronchial artery most usually arises from the first aortic intercostal artery of the right side, which supplies it after having arrived at the right side of the spinal column behind the œsophagus, sometimes it comes direct from the aorta; it proceeds in a tortuous course under the right bronchus, to the root of the right lung, after having given small branches to the œsophagus, the pleura, the back part of the pericardium and the bronchial glands.

The *left* bronchial artery arises immediately from the aorta and passes in front of the œsophagus to the left bronchus, to the posterior side of which it attaches itself. Both bronchial arteries are similarly distributed through the lungs, dividing with the bronchi, along each branch of which they send two or more tortuous twigs. The relation of the bronchial arteries to the other vessels of the lungs will be more particularly noticed in the article LUNG.

The *œsophageal* arteries vary in number from two to seven: they are inferior to the bronchial in size: they arise from the front of the thoracic aorta, and are distributed to the œsophagus, on which they anastomose freely with descending branches of the inferior thyroid from above, in the middle of the œsophagus with the bronchial, and below with branches of the phrenic and coronary artery of the stomach.

The *posterior mediastinal* arteries are numerous and small; they send branches to the œsophagus, thoracic aorta, thoracic duct, absorbents, and cellular membrane of the posterior mediastinum, anastomosing with the bronchial, œsophageal, and some branches of the right thoracic intercostal arteries.

Inferior or aortic intercostal arteries.—Of the eleven intercostal spaces the two superior are mostly supplied with arteries from the superior intercostal branch of the subclavian; and as the first aortic intercostal artery frequently supplies the third and fourth intercostal spaces, we often meet with but eight pairs of intercostal arteries coming immediately from the aorta (*fig.* 78, *d*). The first right aortic intercostal is usually the largest of the series in consequence of giving origin to the right bronchial; the size of the intercostal arteries diminishes in general from above downwards. All the intercostal arteries arise rather from the posterior part of the aorta, those of opposite sides arising very near each other, and sometimes springing from a common trunk. At first they descend obliquely on the vertebral column, at an acute angle to the trunk of the aorta. The right intercostal arteries are longer than the left, in consequence of the position of the thoracic aorta on the left side of the spine. Each artery is lodged at first in a groove on the side of the body of each vertebra, enters the intercostal space passing behind the ganglia of the sympathetic nerve, and immediately divides into two branches, one posterior or dorsal, the other anterior or intercostal. The posterior branch passes backwards through a space above the neck of each rib and below the tranverse process of the superior of the two vertebræ, with which the head of the rib is articulated; it gives some branches to the bodies of the vertebræ, and in passing the intervertebral hole it sends branches inwards to the spinal cord, which anastomose with the spinal arteries. The continuation of the vessel is distributed to the longissimus dorsi, sacro-lumbalis, and other muscles along the side of the spine, as well as to the integuments of the back. The anterior or proper intercostal branch is usually larger than the posterior, and traverses the intercostal space. At first it is situated between the pleura and external intercostal muscle, it shortly divides into two smaller branches, a superior and an inferior, which get between the two layers of intercostal muscles. The inferior branch, usually the smaller, runs forwards along the superior border of the inferior rib, and passes obliquely over its surface to the periosteum covering it. The superior branch, larger than the former, enters a groove in the lower edge of the superior rib, about its angle, in company with the intercostal nerve, and passes forwards between the two layers of intercostal muscles, towards the junction of the rib with its cartilage, where it descends from the rib towards the middle of the intercostal space, and there anastomoses with the anterior intercostal arteries sent off from the internal mammary. Besides supplying the intercostal muscles, pleura, and ribs, the intercostal arteries give several branches, which pierce the external layer of intercostal muscles, and carry blood to the muscles and integuments covering the thorax. The lower intercostals also send branches to the abdominal muscles, diaphragm, and quadratus lumborum, which freely anastomose with the internal mammary, epigastric, phrenic, lumbar, and circumflex iliac arteries.

Anastomoses.—The intercostal arteries have a chain of anastomoses with each other by communicating branches which cross the heads of the ribs. By this means the superior freely communicate with the subclavian by its intercostal artery. Inferiorly, their anastomosis with the phrenic, circumflex ilii, and lumbar arteries, is equally free; internally they anastomose with the arteries of the spinal cord, and in front with the internal mammary and epigastric.

III. *Branches of the abdominal aorta.*—They may be divided into *anterior* and *lateral.* The anterior branches are, the *inferior phrenic, cœliac, superior* and *inferior mesenteric.*

Phrenic arteries.—The phrenic arteries are two in number; they arise from the aorta immediately after its entrance into the abdomen, generally distinct, sometimes from a common trunk, and occasionally one or both arise from the cœliac artery, or one of its branches. Each phrenic artery passes outwards in front of the crus of the diaphragm, and along the upper edge of the renal capsule of its own side. The right artery passes behind the vena cava, and the left behind the œsophagus. They run on the abdominal surface of the diaphragm, and at the posterior edge of the cordiform tendon each vessel divides into an external and an anterior branch. The external branch supplies the fleshy substance of the ala of the diaphragm, and sends several branches towards the external attachments of that muscle which anastomose with the lower intercostal and lumbar arteries; while the anterior branch, coursing round the margin of the cordiform tendon, supplies the anterior part of the diaphragm, and anastomoses with its fellow of the opposite side, behind the ensiform cartilage, sending forwards branches to anastomose with the internal mammary.

Minute branches are given off by the phrenic arteries near their origins to the semilunar ganglia and renal capsules: a small twig from the right phrenic ascends along the vena cava through the diaphragm to anastomose with the comes nervi phrenici of the internal mammary. Another similar twig, given to the œsophagus by the left phrenic, while passing behind that tube, anastomoses with the middle œsophageal arteries.

The *cœliac artery*, called, also, *cœliac axis*, is one of the largest and shortest of the vessels given off by the abdominal aorta. It generally arises from the aorta, between the crura of the diaphragm opposite the junction of the last dorsal and first abdominal vertebra, having the renal capsules and semilunar ganglia on either side of it, with the lobulus Spigelii to the right, the cardiac orifice of the stomach to the left, the superior border of the pancreas inferiorly, and the stomach and lesser omentum in front: it is closely embraced by branches of the solar plexus.

The cœliac artery, which is often scarcely half an inch in length, immediately divides into three branches, the *gastric* or *coronaria superior ventriculi*, the *hepatic*, and the *splenic*, which constitute the tripod of Haller. Sometimes the cœliac axis gives off the *phrenic* and *superior capsular.*

Coronary artery of the stomach.—The coronary artery is the smallest of the three branches furnished by the trunk of the cœliac; it sometimes arises from the aorta itself. Passing upwards, forwards, and to the left, it arrives at the cardiac orifice of the stomach, from which it proceeds forwards and to the right, following the direction of the lesser arch of the stomach until it arrives near the pylorus, where it anastomoses with the pyloric branch of the hepatic. When the coronary artery has arrived at the cardiac orifice of the stomach, it sends one or more branches upwards along the œsophagus which supply that part with blood, and anastomose with the œsophageal arteries from the thoracic aorta: it then sends branches round the cardiac orifice, which nearly encircle that part, and ramify over the great extremity of the stomach, where they anastomose with the vasa brevia of the splenic. In its course along the lesser arch of the stomach the coronary sends many branches over both surfaces of that viscus, which anastomose with each other and with the right and left gastro-epiploic. The terminal branch of the coronary which ends at the pylorus is sometimes called superior pyloric. Sometimes the coronary artery gives off the right hepatic immediately before reaching the cardiac orifice of the stomach.

The *hepatic artery* passes forwards and to the right under the lobulus Spigelii to the neck of the gall-bladder. In this part of its course it gives a few twigs to the gastro-hepatic omentum and the inferior surface of the liver; when it reaches the pylorus, it gives two considerable branches called the *pyloric* and the *right gastro-epiploic.* The *pyloric* passes from right to left along the lesser arch of the stomach, where it meets the coronary with which it anastomoses, sending several branches over the anterior and posterior surfaces of the stomach to anastomose with the right gastro-epiploic artery. The *right gastro-epiploic* artery, much larger than the pyloric, arises after that vessel; it passes downwards behind the pylorus, and arrives at the greater arch of the stomach, along which it courses from right to left and anastomoses with the left gastro-epiploic. While passing behind the pylorus, it gives several branches to the pancreas and duodenum, one of which, somewhat larger than the rest, called pancreatico-duodenalis, lies concealed between the duodenum and head of the pancreas, and anastomoses with the branches which the pancreas receives from the superior mesenteric. As the gastro-epiploic artery courses along the greater arch of the stomach, it gives off numerous branches, some of which ascend on the anterior and posterior surfaces of the stomach, and anastomose with the coronary and pyloric; others descend in the anterior layer of the great omentum: some branches from these ascend in the posterior layer of this fold of membrane until they reach the arch of the colon, where they anastomose with the colic branches of the superior mesenteric.

After having given off these branches, the hepatic artery ascends towards the right within the capsule of Glisson, in front of the vena porta, and to the left of the ductus communis choledochus. Having reached the transverse fissure of the liver, it divides into the *right* and *left hepatic* arteries which enter the liver by divisions corresponding to those of the vena porta, the right branch having previously given off the cystic artery, which arises opposite the junction of the cystic and common hepatic ducts, attaches itself to the neck of the gall-bladder, and soon divides into two branches, one of which ramifies over the inferior surface of that reservoir, while the other sinks between the liver and the gall-bladder. For further particulars relating to the hepatic artery vide Liver.

The *splenic* is the largest of the three branches of the cœliac. Immediately after its origin it passes with numerous contortions to the left, behind the stomach and along the superior border of the pancreas to the fissure of the spleen. In this course it gives off *pancreatic* branches *(pancreaticæ magnæ et parvæ)*, which anastomose with the pancreatic branches of the right gastro-epiploic. It gives a large branch, the *left gastro-epiploic*, which sometimes arises from one of the branches in which the splenic terminates. This branch passes onwards to the left until it reaches the greater arch of the stomach, along which it descends, passes to the right until it meets the right gastro-epiploic, with which it anastomoses. In its course it gives off, like the right gastro-epiploic, superior branches, which pass over the anterior and posterior surfaces of the stomach to anastomose with the branches of the coronary and inferior branches which descend in the great omentum, where they have a similar distribution with the descending branches of the right gastro-epiploic: near the fissure of the spleen, the splenic artery divides into five or six branches, which anastomose by arches, and enter the substance of that organ. Before entering the substance of the spleen these branches give off large vessels, called *vasa brevia*, which bend to the right, and are distributed to the great extremity of the stomach, spreading over its anterior and posterior surfaces, where they anastomose with branches of the coronary and right gastro-epiploic.

The *superior mesenteric* artery, often larger than the cœliac, arises from the aorta immediately after the cœliac; sometimes from a trunk common to both vessels, as in the tortoise. This artery is at first concealed by the pancreas, it descends perpendicularly behind that gland and crossing the termination of the duodenum arrives at the root of the mesentery, between the two layers of which it descends. In the middle of this fold of the peritoneum it forms a considerable curve, the convexity of which is to the left, and directs its course towards the termination of the small intestine in the right iliac region, forming near its termination a second curve, the concavity of which is to the left. Near its origin this artery gives some branches to the duodenum and pancreas, by means of which it anastomoses with the branches of the hepatic and splenic sent to these organs: in the mesentery it sends off from its left side the arteries of the small intestines, and from its right the arteries which it supplies to the great intestine.

Arteries of the small intestines.—These arise from the left side of the superior mesenteric, varying in number from fifteen to twenty; the superior are longer and larger, those which succeed them appear to diminish progressively in length and size, they all advance between the two layers of the mesentery to the concave side of the intestine; at a certain distance from their origin they divide into secondary branches which diverge from each other at acute angles; these secondary branches subdivide into still smaller branches, which, diverging in a similar manner, form arches of anastomoses with corresponding branches of the adjoining arteries; the convexities of these arches are all turned towards the intestine, and from them numerous branches arise, which, by dividing and anastomosing like the larger trunks, form a second series of smaller arches; other branches arising from the convexities of these arches divide and anastomose to form still smaller and more numerous arches; thus we have three, sometimes four, and occasionally five series of arches, formed by the subdivisions of these arteries before they reach the intestine, and presenting in the mesentery a network with large meshes. From the convexities of the extreme arches which form the outer border of this network, thousands of small arteries pass in a straight direction to the tube of the intestine; these form two series, an anterior and a posterior, which apply themselves to the opposite surfaces of the intestine, and anastomose with each other on its convex border. The detailed description of their further distribution will come under consideration in the article Intestinal Canal.

Colic arteries. — The superior mesenteric sends off three, sometimes only two, branches from its concavity, called *right colic* arteries, distinguished as *superior* or *colica media*, *middle* or *colica dextra*, and *inferior* or *ileo-colic;* when there are but two, the superior and middle form but a single trunk; the inferior is generally distinct.

The *right superior colic* or *colica media* arises a few inches distant from the origin of the superior mesenteric; it passes forwards between the layers of the meso-colon towards the middle of the transverse colon, and divides into a right and left branch; the right follows the right part of the transverse colon, and anastomoses with the superior branch of the colica dextra; the left branch follows the left portion of the transverse colon, and communicates with the left colic branch of the inferior mesenteric artery.

The *colica dextra* or *middle right colic* artery arises close to the colica media, sometimes from a trunk common to both, and sometimes from the ileo-colic. After its origin it passes forwards, upwards, and to the right in the meso-colon towards the ascending colon, and divides into two branches; one superior ascends to anastomose with the right branch of the colica media, the other descends along the concavity of the ascending colon, and communicates with the ascending branch of the ileo-colic.

The *ileo-colic*, *cæcal*, or *inferior right colic* passes downwards, and to the right towards the cœcum, and then divides into three branches; the first ascends in the meso-colon, and anastomoses with the descending branch of the colica dextra; the second communicates in the mesentery with the termination of the superior mesenteric; and the third, arising in the angle between the two preceding, passes behind the junction of the ileum with the cœcum: at this place it gives off a branch which forms a small arch in the mesentery of the vermiform appendix, and then divides into two branches, one of which passes upwards on the colon, and the other descends on the cœcum. The colic arteries, by their anastomoses with each other, form arches, from the convexities of which, turned towards the intestine, numerous branches arise; each of these again divides into two, which with the contiguous vessels form smaller arches, and straight branches finally arise from the ultimate arches, which, passing on either side of the intestine, include it between them, and anastomose on its convex edge.

In the fœtus we have the *omphalo-mesenteric* artery arising from the superior mesenteric; this vessel, which passes along the umbilical cord to the vesicula alba, becomes obliterated towards the end of the second month of gestation.

The *inferior mesenteric* artery arises from the front of the aorta to its left side, at about an inch or an inch and a half above the origins of the primitive iliacs; it sometimes arises from the left primitive iliac, especially when the aorta has divided higher than usual; instances of the absence of this artery are very rare, but interesting as presenting an example of the normal condition in birds and reptiles, in which the inferior mesenteric artery is much reduced in size or entirely absent.

The inferior mesenteric artery runs obliquely downwards and to the left, and gets between the layers of the left iliac meso-colon, where it divides into many branches, distributed to the left portion, and sigmoid flexure of the colon and the rectum; the superior branches are distributed to the descending portion and sigmoid flexure of the colon, and are called *left colic* arteries, while the lower branches go to the rectum under the name of *superior hæmorrhoidal* arteries. The left colic arteries are three in number, the *superior*, *middle*, and *inferior*. The *superior left colic* is the largest of the three; it arises from the inferior mesenteric immediately after its origin, passes transversely to the left, and divides near the left lumbar colon into two branches, one of which ascends to the transverse meso-colon, and anastomoses with the colica media of the superior mesenteric; the other branch descends towards the left iliac meso-colon, where it anastomoses with the ascending branch of the middle left colic.

The *middle left colic* is sometimes a branch of the preceding. It divides into two branches; one ascends along the left colon, and anastomoses with the descending branch of the left superior colic; the other, inferior, smaller communicates with the ascending branch of the left inferior colic.

The *inferior left colic* goes to the sigmoid flexure of the colon, and soon divides into two branches; one superior anastomoses by an arch with the descending branch of the preceding, and the other inferior meets a branch of the hæmorrhoidal in the meso-rectum. They are distributed to the intestine in a similar manner with the branches of the right colic arteries, as already described.

When the inferior mesenteric has given off the colic arteries, it diminishes, takes a perpendicular direction, and reaches the posteror surface of the rectum lodged between the layers of the meso-rectum, here it takes the name of *superior hæmorrhoidal* artery. It soon divides into two branches, a right and left, which apply themselves to the sides of the rectum, sending branches backwards and forwards round that intestine, by which they communicate with each other, and anastomose below with the middle and inferior hæmorrhoidal arteries; some branches anastomose with the lateral sacral of the internal iliac.

The lateral branches of the abdominal aorta consist of the *capsular*, *renal* or *emulgent*, *spermatic arteries*, small twigs to the ureters and adipose substance in the vicinity of the aorta, and the four pairs of *lumbar arteries*. For an account of the capsular, emulgent, and spermatic arteries we must refer to the articles Renal Capsule, Kidney, and Testicle.

The *lumbar* arteries are four in number on each side (*fig.* 78, *f*); they arise from the lateral and posterior part of the aorta nearly at right angles, they pass outwards across the middle of the bodies of the four superior lumbar or abdominal vertebræ to the roots of their transverse processes, covered by the psoas muscle and the crura of the diaphragm. When the lumbar arteries have reached the roots of the transverse processes of the lumbar vertebræ, they divide each into two branches, one posterior and the other anterior.

The posterior or dorsal branches are smaller and pass backwards between the transverse processes of the lumbar vertebræ, opposite the intervertebral foramina, where they each send a branch inwards to the spinal cord and cauda equina; they then plunge into the substance of the great sacro-lumbar mass of muscles, in which they are lost, anastomosing frequently with each other, and with the dorsal branches of the lowest intercostal and ileo-lumbar arteries. The continuations or anterior divisions of the lumbar arteries pass outwards between the psoas and quadratus lumborum muscles, to which they give small branches, as well as to the diaphragm, kidney, renal capsule, and surrounding cellular membrane; they then continue their course forwards between the layers of the abdominal muscles, in company with branches of the lumbar nerves, and anastomose with the lower intercostals, mammary, epigastric, and circumflexa ilii.

The *middle sacral* artery arises from the back part of the abdominal aorta, immediately above the origins of the primitive iliacs, from one of which it arises in some rare cases, it descends exactly over the middle of the anterior surface of the bodies of the last abdominal vertebra, false vertebræ of the sacrum and os coccygis, lying close on the surfaces of those bones; the branches which it gives off are distributed in a lateral direction; the first is the largest and not unfrequently is the fifth lumbar artery, the size of which sometimes exceeds that of the continuation of the trunk of the middle sacral itself. This branch divides into an anterior and a posterior, the distribution of which is similar to that of the superior lumbar arteries. Two transverse branches usually arise from the middle sacral on the body of each false vertebra; these passing outwards give branches to the periosteum and the substance of the sacrum, anastomose with branches of the lateral sacral arteries, and enter the anterior sacral foramina, where they give some branches to the origins of the sacral nerves, and emerging from the posterior sacral foramina are lost in the muscles arising from the back part of the sacrum; finally, the middle sacral terminates at the extremity of the coccyx in small branches, which it sends to the rectum and surrounding fat.

The middle sacral artery is sometimes found double; in the fœtus this artery is proportionally larger than in the adult, especially in the earlier periods of gestation. In some animals, the size of the middle sacral artery is scarcely inferior to that of the aorta itself, as in the cetacea and fishes. In all animals furnished with tails, the size of this artery bears a constant relation to the size of that member.

Aneurism rarely affects any of the branches of the aorta above described; it, however, occasionally occurs in the cœliac or mesenteric arteries, or some of their branches. An interesting case of aneurism of the hepatic artery unattended by pulsation during life, and which produced jaundice by pressing on the ductus communis choledochus, is reported by Dr. William Stokes, in the Dublin Journal of Medical and Chemical Science, for July 1834. We once witnessed the dissection of a female aged forty, under the care of the late Professor Todd, in the Surgical Hospital of the House of Industry in Dublin, in whom three distinct aneurisms of large size were found in the epigastric region; one of the hepatic artery, which communicated with that vessel by a longitudinal fissure, and which had opened into the cavity of the gall-bladder; one of the trunk of the coronary artery of the stomach, and a third of the splenic artery. A remarkable feature in this case, and that of Dr. Stokes, was the absence of pulsation during life, in consequence of which the nature of the disease was not discovered until the post-mortem examination; the above circumstance may be attributed to the want of resistance in the surrounding parts, and it is one which frequently obscures the diagnosis of abdominal aneurisms.

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(J. Hart.)

ARACHNIDA; *αραχνη*, *aranea*; Eng. *arachnidans*; Fr. *arachnides*; Germ. *Spinne*; Ital. *Ragni*.

This class of animals was for a long time confounded with that of insects, but it has been distinguished therefrom by many modern naturalists, and more especially by Lamarck, who has applied to it the term 'arachnides,' now universally adopted.

The characters indeed which the arachnidans present are perfectly distinct, and prevent them from being confounded either with crustaceans or insects, although one cannot avoid perceiving that they have numerous relations with the animals of these two classes, and they are consequently placed in natural arrangements between the crustaceans and insects.

Zoologists have assigned the following characters as peculiar to and distinguishing this class.

Body divided into thorax and abdomen; apterous. *Legs*, eight in the adult state. *Head* continuous with the chest. *Eyes* smooth. *Sexual orifices* situated either on the thorax or base of the abdomen.

To these external characters may be added others derived from the anatomical conditions of different organs. Thus all arachnidans possess exclusively an aerial respiration, either effected by a sort of lungs, or by means of tracheal tubes, as in insects. This difference in the respiratory organs is accompanied with one not less marked in those of circulation; for example, all the pulmonary arachnidans possess vessels which carry blood, while, on the contrary, all those which have tracheæ are deprived of bloodvessels. Lastly, the latter species (or trachearies) alone undergo metamorphoses analogous, in some respects, to those of insects; while the former (or pulmonaries) suffer only changes of integument. We shall treat further on these peculiarities hereafter.

Our object here not being to treat of classification, we shall refer the reader for this subject to the works of Cuvier, Leach, Latreille, Walcknäer, Dugès, and limit ourselves at present to a tabular exposition of the principal divisions and subdivisions admitted in this class down to the genera with which it is most essential to be acquainted.

Latreille, whose method is that most generally adopted by zoologists of every country, divides the arachnidans into two great orders, as follows:—

Class.		*Orders.*
ARACHNIDA.	*Pulmonary sacs* for respiration, 6 to 12 *ocelli*.	PULMONARIA.
	Tracheæ for respiration, not more than 4 *ocelli*.	TRACHEARIA.

The same author establishes in the first order two families, which are characterized as follows:

		Families.
1*st Order.* ARACHNIDA PULMONARIA.	*Palpi* simple, pediform; *mandibulæ* armed with a moveable and perforated claw, emitting a poisonous liquid .... *Abdomen* inarticulate, terminated by spinnarets	.... *ARANEIDÆ.*
	Palpi produced, cheliform, or shaped like pincers .... *Mandibulæ* provided with a moveable digit .. *Abdomen* articulate, without spinnarets	........*PEDIPALPI.*

M. Walcknäer, who has made a special study of the family of *araneidæ* or *spinning arachnida*, and who has published many works on their methodical distribution and their habits of life, has very recently considered them with the express view of arriving at a natural arrangement of them; the result of his labour may be seen in the following

TABLE OF THE SUBDIVISION OF THE ARANEIDÆ, OR ARACHNIDA FILOSA INTO GENERA.

Family	Mandibles	Eyes	Arrangement of eyes	GENERA.	Tribe	Division	Habitat
First Family. ARANEIDÆ, Spiders.	*Mandibles* articulated horizontally; moving vertically	8 eyes.	*Eyes* aggregated ..	Mygale	*LATEBRICOLÆ*, hiding in holes and fissures......	*Venantes*, incessantly running or leaping about the vicinity of their abode to chase and catch their prey...............	*Terrestres*, living on land or in holes in the ground.
				Oletera			
				Filistata			
			Eyes segregated ..	Missulena			
				Sphodros			
	Mandibles articulated vertically, or on an inclined plane; moving laterally	6 eyes.	*Eyes* anterior	Dysdera	*TUBICOLÆ*, inclosing themselves in silken tubes..		
				Segestria			
			Eyes, anterior and lateral	Uptiotes	*CELLULICOLÆ*, sheltering themselves in small cells		
				Omosites			
				Scytode			
		8 eyes.	*Eyes*, anterior and lateral, very unequal in size	Lycosus	*CURSORES*, running swiftly to catch their prey....		
				Dolomedes			
				Storena			
				Ctenus			
				Hersilia			
				Sphasus			
				Dolophenes			
				Myrmecia	*SALTATORES*, leaping and springing with agility to seize their prey		
				Eresus			
				Platiscelum			
				Attus			
				Delena	*LATERIGRADÆ*, walking and running sideways or backwards; occasionally throwing out threads to entrap their prey	*Vagantes*, wandering abroad & incessantly spying out for prey. No fixed residence, except at the period of oviposition	
				Thomisus			
				Selenops			
				Eripus			
				Philodromus			
				Sparassus			
				Clastes			
			Eyes anterior, almost equal in size..............	Clubiona	*NIDITELÆ*, going abroad, but making a web for their nests, whence issue threads to entrap their prey	*Errantes*, prowling about the neighbourhood of their nests or near the threads which they throw out to catch their prey	
				Drassus			
				Clotho	*FILITELÆ*, going abroad, but spreading long threads of silk about the places where they prowl in order to entrap their prey		
				Emyo			
				Latrodectus			
				Pholcus			
				Artema			
				Tegenaria	*TAPITELÆ*, spinning great webs of a close texture like hammocks, and dwelling therein to catch their prey	*Sedentes*, spinning large webs to entrap their prey, lying wait in the middle or at the side	
				Lachesis			
				Agelena			
				Nyssus			
				Epeira	*ORBITELÆ*, spreading abroad webs of a regular and open texture, either orbicular or spiral, and remaining in the middle or on one side to catch their prey		
				Tetragnatta			
				Uloborus			
				Zosis			
				Lynyphia	*RETITELÆ*, spinning webs of an open meshwork and of an irregular form, and remaining in the middle or on one side to seize their prey		
				Episina			
				Theridion			
				Argyroneta	*AQUITELÆ*, spreading filaments in the water to entrap their prey	*Natantes*, swimming in water, and there spreading their filaments to entrap their prey	*Aquaticæ*, living in water

Up to the present time M. Walcknaer has not published on the second family of Arachnidans or the *Pedipalps*, and few authors have studied them. Latreille, however, has treated of them with sufficient detail in the '*Regne Animal*,' and more recently M. Ehrenberg has carefully investigated one of the principal groups. The following table will present the principal divisions adopted by these two authors.

Subdivision of the Pedipalps into Genera.

Family	Characters	Group	Subdivision		GENERA.
Second Family. PEDIPALPI, Scorpions.	*Stigmata* 4, situated near the origin of the abdomen, *mandibles* unguiculate, or terminated by a moveable claw. No thoracic *combs*..	*THELYPHONIDÆ.*	Abdomen with a caudal filament		*Phrynus.*
			Abdomen without a caudal filament		*Thelyphonus.*
	Stigmata 8, situated along the inferior lateral part of the abdomen; *mandibles* chelate, or terminated by two digits, the exterior of which is moveable. Combs on the inferior part of the thorax	*SCORPIONIDÆ*	6 Eyes	*Scorpio*, LINNÆUS	*Scorpio.*
			8 Eyes		*Buthus.*
			12 Eyes		*Androctonus.*

The second order of Araehnidans, or the Trachearies (*Trachearia*) has in general been less perfeetly studied than the first; it ineludes many anomalous species, of whieh the greater part eseape observation from their extreme minuteness. Such are, *e. g.* the Acaridæ, or mite-tribe, whieh have recently exereised the patience of our learned friend M. Dugès, Professor of the Faculty of Medieine at Montpellier.—Whilst referring the reader to his paper inserted in the Annales des Seienees (1834), we have thought it convenient to present here a Table of the seetions and genera whieh he has founded in that tribe of Arachnidans.

Table of the sub-divisions of the Tracheary Arachnidans.

Order			*Families.*		*Tribes.*	*Sections.*	*Genera.*
2d Order. ARACHNIDA TRACHEARIA	Thorax, with divisions or articulations.	*Abdomen* very distinct, large, and annulate; *Palpi* very large, pediform, or cheliform.	*PSEUDO-SCORPIONIDÆ*				Galeodes. Chelifer.
		Abdomen rudimentary, not annolate: *Palpi* small, filiform, and provided with a hooked claw at the extremity.	*PYCNOGONIDES*				Pycnogonum. Phoxichilus. Nymphan.
	Thorax, without articulations, or at most divided into two by a contraction.		*HOLETERÆ*	*Mandibles* very conspicuous, free, terminated by a didactyle nipper; *Abdomen* annulate; no metamorphosis	*Phalangidæ*		Phalangium. Siro. Trogulus.
				Mandibles and other oral organs ordinarily supported or surrounded by a lower lip in the form of a sheath. *Abdomen* not annulate; a metamorphosis in many.	*Acaridæ*	*Trombidiei.* (palpi raptores)	Raphignatus. Tetranychus. Rhyncholophus. Smaridia. Trombidium. Erythræus.
						Hydrachnei. (palpi anchorales)	Atax. Diplodontus. Arrenurus. Eylais. Lymnochares. Hydrachna.
						Gamasei. (palpi filiformes)	Dermanyssus. Gamasus. Uropoda. Pteraptus. Argas.
						Ixodei. (palpi valvulares)	Ixodes.
						Acarei. (palpi adherentes)	Hypopus. Sarcoptes. Acarus.
						Bdellei. (palpi antenniformes)	Bdella. Scirus.
						Oribatei. (palpi fusiformes)	Oribates.

Of the external covering or tegumentary system.—Although the external covering of the arachnidans varies in consistence, according to the part of the body which is examined, yet it may be said in general to be more or less soft, rarely acquiring the solidity of the integument of certain insects, and still less the hardness of that of many crustaceans.* Where it is of the greatest consistency it is elastic, of a deep brown colour, and has an aspect analogous to horn. In chemical composition, however, it is always widely different, as has been proved by the researches of M. August Odier, and some other chemists. It contains, in fact, a substance *sui generis*, called 'chitine,' which is insoluble in potassa, but, on the contrary, is soluble in warm sulphuric acid, does not turn yellow with nitric acid, and does not curl up when burnt, but leaves an ash, which, if the part experimented on is sufficiently thick, preserves the form of the organ.

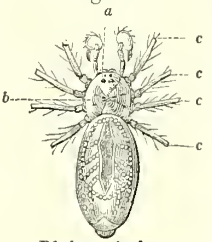
The solidity of the outer covering is generally greater on the thorax than on the abdomen. The *genera scorpio*, *phrynus*, *thelíphonus*, and *phalangium*, afford an exception to this rule, the rings of the abdomen being distinct and solid, especially on the dorsal aspect.

In the spiders properly so called, *(araneæ,)* and in the greater number of the mites *(acari)*, the skin of the abdomen is very soft, coriaceous, papiraceous, or even membranous, transparent, and susceptible sometimes of being greatly extended. It is on this account that the abdominal segment of the body shrinks and loses its form after death, and from the transparency of the integuments the same arachnidans present during lifetime the various markings and lively colours which depend on a kind of pigment situated in the interior of the body.

The head, as we have remarked in our exposition of the characters of the class, is always consolidated with the thorax; this is readily ascertained to be the fact in scorpions and spiders, and in order to express this disposition, which obtains also in many of the crustacea, the two united segments are termed 'cephalo-thorax;' the term abdomen is applied to the part properly so called, and thus the body of the arachnidans may be divided into two parts. The abdomen may be either *sessile* or *pediculate*, i. e. it may either inclose at its anterior margin the posterior part of the thorax, as in the scorpions, or it may adhere to the thorax by a very circumscribed part of that margin, as in the spiders properly so called. Anatomically speaking, the abdomen has a very simple structure: it is formed of annular segments sometimes distinct and hard, as in the scorpions; sometimes blended together and soft, as in the spiders and mites.

The other division of the body or cephalothorax is not so simple. To facilitate the study of this part it is necessary to consider the cephalic portion separately from the thoracic division. This it is easy to do, where, as in many cases, the junction of the two parts is perfectly distinct, and made obvious by the existence of a furrow along all the whole superior part of the line of union, (see the traces of it in the thorax of a pholque, *pholcus rivulatus*, *fig.* 79.) But in every case the head (*a*) is recognizable by constant characters: it supports the eyes and all the pieces belonging to the oral apparatus, while the thorax (*b*), on the contrary, gives insertion to the four pairs of legs, which on account of their extreme length are represented in the figure as truncated.

Fig. 79.



Pholcus rivulatus.

The head is often as narrow as the chest, abruptly truncated anteriorly, and terminated by a point posteriorly, so that it appears by its backward prolongation to separate the right from the left side of the thorax, and to be placed between them like a wedge, (as in the *pholcus.*) The suture is very close, and sometimes so far effaced that it is no longer possible to decide where the head terminates and the chest commences. We have already observed that the head supports the eyes on its upper part, and has the oral instruments attached to its lower surface. These consist, first, of a pair of *mandibles* or *forciples;* secondly, of a pair of *maxillæ;* thirdly, of a sternal *labium.*

The number of annuli or segments which enter into the composition of the head of an arachnidan may yet be determined at some future period: we have made some attempts to unravel this subject, but our observations are not yet sufficiently matured to permit us to decide so difficult a question.

Our researches on the thorax of articulate animals have led to more decisive results, which we shall now expound, but for the complete understanding of which we must refer the reader to the article Insecta, where a more general theory of the thorax, and a description of all the pieces that enter into its composition will be given. In the arachnidans many of these pieces are entirely wanting; and their thorax is consequently more simple than that of insects: it is even more simple than the thorax of crustaceans, to which, however, it bears a great resemblance in many points. If, for example, we take a large spider, as a *mygale avicularia*, and strip off the hairs which clothe the thorax, we shall easily perceive a plate, or plastron, intermediate to the right and left series of legs. This plastron is the sternum, or, to speak more correctly, the union of several sternums, which, were it not for this union, would manifest themselves as four distinct pieces; that is to say, corresponding in number to the pairs of legs which arise from them. This sternal plas-

* This composition being precisely analogous to that of the integuments of insects, we shall treat of it in the article relating to these animals.

tron is distinctly shewn in *fig.* 100, *e*, which represents the inferior surface of the body of the house-spider, (*tegenaria domestica*.)

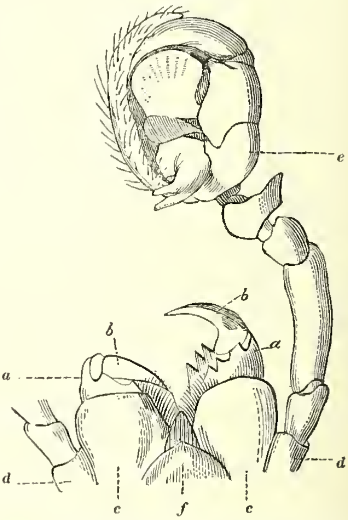
On the upper surface of the chest we find another plate much more extended than the sternum, and joined anteriorly with the head by means of a fissure or triangular V-shaped notch which receives it. This plate or dorsal shield exhibits divisions or rather lines of suture which the eye readily distinguishes. They represent arcs of circles arising from the base of the legs and all ending in the centre of the thorax, where there is a depression varying as to extent and depth according to the individual. In other arachnidans this structure is not so clearly shewn on account of the close union of the different pieces; but it is easy to detect or at least explain the unimportant modifications which obtain in these cases. In the figure, which we have taken from Savigny, of the *pholcus rivulatus*, the traces of the division may be readily followed, (*fig.* 79, *b*.) Continued comparative researches have convinced me that this dorsal plate of the thorax of the *araneidæ* is formed, not of the dorsal pieces of the thorax of insects, but only of the lateral pieces or those of the flancs. For the arachnidans being deprived of wings, the intermediate thoracic element or tergum, so largely developed on account of the presence of those organs in the thorax of insects, being no longer necessary, has completely disappeared. How has this taken place? The flancs (*pleuræ*) which in insects were divaricated and pushed to the sides by the tergum, when that obstacle was removed, have mutually approximated and become united together in the middle line, precisely at the place where the little depression exists which we have already mentioned.

We believe that we have placed these facts beyond all doubt in our 'Researches on the Thorax of Articulate Animals,' presented to the Academy of Sciences of Paris in 1820.* Now it is worthy of remark that what has happened to the arachnidans, being animals deprived of wings, is also found in the crustaceans, which are equally destitute of these organs. Only that there exists in some of the latter, as the decapods, a vast carapace which occurs independently of the flancs, and covers them. For if the carapace is raised in a crab, the flancs or pleuræ are seen beneath, extending obliquely towards one another as in the thorax of a *mygale*, with this single difference, that in the *cancer*, where the carapace covers the flancs and protects them as well as the internal soft parts, the *pleuræ* or side pieces remain divaricated and are not joined at their apices as in the *mygale*.†

Digestive system.—The arachnidans, whose habits have been made the subject of observation, feed for the most part on animal matter, not in a state of decomposition or even recently dead, but in the living state. They either boldly seize their prey, which consists of insects of greater or less size, or they attach themselves to animals much larger than themselves, and live parasitically upon their blood or some other nutritious fluid. The latter species are generally very minute: many of them, as the mites (*acari*), require our best optical instruments for their detection. The above differences in habits of life are accompanied with important modifications in the organs of nutrition, and especially in the oral apparatus, which we proceed to describe.

In the non-parasitic species, as the pulmonary and part of the tracheary arachnidans, the mouth consists essentially, first, of two *mandibulæ* or forciples (*fig.* 80, *a*) in close ap-

Fig. 80.



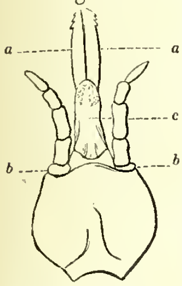
position, endowed with little lateral motion, but rather acting vertically and provided each with a hooked claw (*b*), which, near its point, is perforated, and emits a poisonous fluid, secreted by a gland, hereafter to be described. In other arachnidans of the same order the *mandibulæ* are a species of pincers, one nipper of which is alone moveable, as in the scorpions. Secondly, of two *maxillæ* (*c c*), each in the form of a more or less flattened and villous lobe, provided with a palp or jointed appendage (*d*) projecting more or less from the mouth, and terminated sometimes by pincers as in the *scorpions*, sometimes by a simple

* See the Report by Cuvier, in the Analysis of the Works of the Royal Academy of Sciences for the year 1820.

† We must again refer to the articles CRUSTACEA and INSECTA for the full comprehension of the facts which presuppose an anatomical knowledge of the external covering of the animals of these two classes. To those who already possess that information I shall observe that a single piece of the flancs of insects (*epimera*) forms the back-part of the thorax of spiders; the other piece (*episternum*) already in a rudimentary state in the crustaceans, has completely disappeared from the thorax of the arachnidans, each segment of which consequently consists only of two pieces, the *sternum* below, the *epimera* above.

claw, as in the spiders, at least the females, for in the males this palp is frequently the seat of a singular apparatus (*e*), hereafter to be described. Thirdly, of a sternal *labium (f)*, which, as its name implies, is inserted into the sternum, and does not give origin to any articulated appendage or palp. With respect to the composition of the mouth in the parasitic species, such as most of the mites, and we may take as an example an *argas*, although it is concealed under the form of a beak, sometimes with a sharp point, yet it is essentially the same. The principal difference consists in the dart-shaped mandibles (*a a*), being joined together so as to form a kind of lancet, the sides of which are sometimes denticulated, so as to cause them to adhere firmly to the flesh which they have penetrated. The *maxillæ* with their palp (*b*) and the inferior *labium* (*c*) are here more or less intimately blended together, so as to form a case or sheath. In some instances the maxillary palp remains free, as in the *argas*.

Fig. 81.



Head of a mite (Argas.)

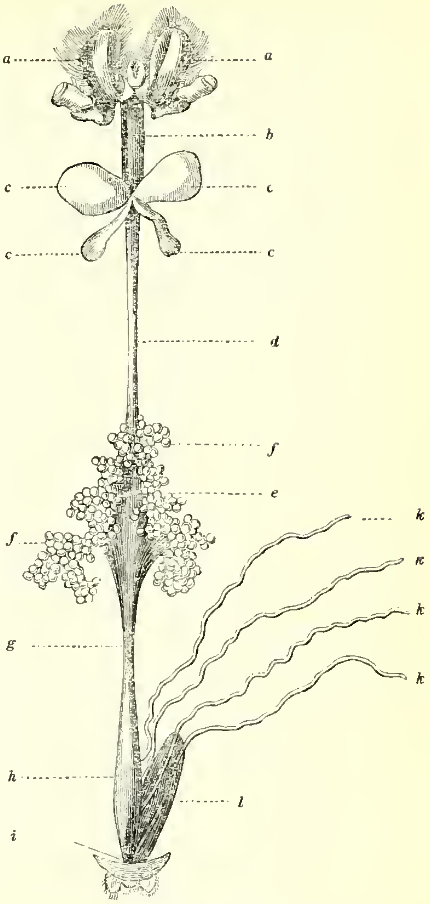
Savigny admits that in the interior of the mouth of arachnidans there exist three pharyngeal orifices, and not a single one as in crustaceans and insects. These three orifices, which are of almost imperceptible minuteness, are situated at some distance from one another, and disposed in a triangular form. He has observed this structure in spiders, scorpions, and phalangians: but he represents only two orifices in a genus allied to *galeodes*. Latreille denies the fact, and Treviranus, in his anatomical description of arachnidans, mentions only one pharyngeal orifice.

However this may be, Savigny confines the assumption of food in spiders to a true suction: "The mandibles," says he, "do not serve for bruising the food, but for seizing it, and for piercing and retaining it in firm contact with the maxillæ; these subject it to alternate pressure, and express the juices which afterwards pass into the pharynx."* This is a matter of daily observation when a spider seizes an insect.

The intestinal canal of the arachnidans is always short, and is never disposed in convolutions as in certain herbivorous insects. This disposition is in accordance with their predaceous habits, and confirms the general rule, (but which to our knowledge is not without many exceptions,) that the intestinal canal is longer in herbivorous than carnivorous animals.

In the spiders, (araneæ,) and we may take the common species (*tegenaria domestica*) as an example, the alimentary canal (*fig*. 82) communicates with the mouth between the maxillæ (*a a*) by an œsophagus, rather short and of a delicate texture (*b*). This terminates in four sacs (*c*), which M. Treviranus calls "stomach," but which, in our opinion, merit rather the name of gizzards; the digestive tube then continues, as a straight narrow canal (*d*) of moderate length, which dilates (*e*) and adheres, by its parietes, to a kind of epiploon filled with adipose granules (*f*). Posteriorly the dilated part becomes stronger in texture, insensibly contracts (*g*), then undergoes a second dilatation (*h*) before it opens into the rectum (*i*). It is near the latter part, in a kind of pouch, that the slender vessels open which M. Treviranus calls biliary vessels, and which he is, with reason, surprised to see terminating in so extraordinary a position. These vessels, in fact, which characterize so well by their presence the chilific stomach of insects, and are situated in these animals more or less anteriorly, always preceding the small intestines which have a greater or less length, terminate in the spiders in the rectum itself, and close to the anus.

Fig. 82.

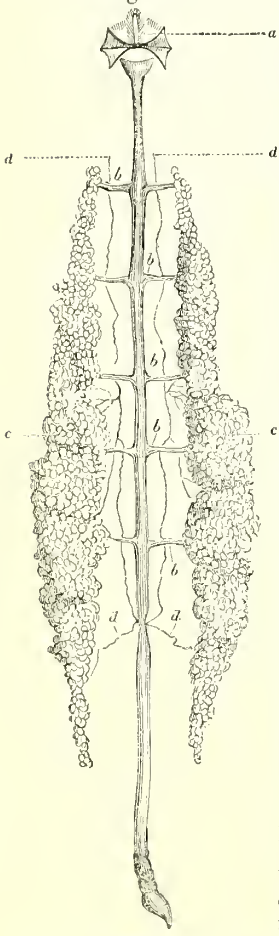


Tegenaria domestica.

* See Description of Egypt, Arachnidans, pl. 8, fig. 7, E, y, y. Savigny at first admitted but two pharyngeal openings, (Mémoir sur les Animaux sans Vertebres, p. 57); but subsequently admitted three.

Now if the observations of M. Treviranus are correct, and the four vessels which he describes are really analogous to the biliary tubes of insects, we do not hesitate to consider all the part which precedes and is intermediate to them and the four sacs, as the stomach, or chilific cavity. It would thus result, that the *tegenaria domestica* would be deprived of an intestine properly so called, and would possess no part destined to transmit along a greater or less extent the *residua* of the digestive process. And, indeed, such residua must necessarily be very inconsiderable in an animal which is sustained by juices, and these already animalized. We are, indeed, led to this conclusion by the structure presented by the hemipterous insects which are nourished, like the spiders, by suction, and which also have the intestines, properly so called, so short that the biliary vessels, which always accompany the posterior extremity of the stomach, are found close to the anus. We may form an idea of this disposition by casting an eye over the beautiful figures which our friend M. Leon Dufour has just published in his " Anatomical and Physiological Researches on the Hemiptera."

Fig. 83.



Scorpio.

In the alimentary canal of the scorpions the biliary vessels *d d* are inserted much higher up, but this is not the only peculiarity which the anatomy of these animals presents. Their digestive tube extends without any marked dilatation straight from the mouth (*a*) to the anus which opens at the extremity of the tail. It presents in this course a very singular structure: five small canals (*b*) go off at right angles from either side, above the place of communication of the biliary vessels, and terminate by ramifying in the fatty masses which make a sort of epiploon (*c*.) This truly remarkable structure is not, however, so anomalous as might be supposed, especially if we regard as cœcums these kind of lateral vessels. For the alimentary canal presents a still more ramified condition in some crustaceans,—we would cite as an example the argulus studied by Jurine;* and in another animal of the same class which M. Milne Edwards and myself† have made known under the name of *Nicothoë*, the intestinal canal sends out considerable lateral prolongations. In the leech, and especially the *Clepsina*, there exist numerous cœcums. Lastly, certain minute arachnidans (acaridæ) are remarkable for analogous lateral dilatations. It is to be observed that all these beings are sustained by animal juices, and the great part, for the better gorging of the same, are fixed either momentarily or during their whole life upon the body of their victim.

We now come to speak of the epiploon and the fatty globules which it contains. The fat, or the substance which appears as such, is extremely abundant in the bodies of insects and arachnidans. In the latter it assumes the form of granular masses or globules of various colours, and sometimes these are united together by a thin membrane. In the araneæ the fat is especially abundant in the abdomen, of which, indeed, it determines the form. The use of this fatty apparatus cannot be mistaken, and it has been placed beyond doubt by experiment, that it supplies the place of nourishment to the animal, either when the latter passes the winter in a state of torpidity, like the hibernating animals, or when in particular seasons circumstances are not favourable for catching prey.

Respiratory system.—The division which has been established in the class *Arachnida* of *Pulmonaries* and *Trachearies* indicates that there are in these animals two very different modes of respiration. In both cases the atmosphere penetrates to the interior of the body by orifices situated on different points of the body, and called *stigmata*. The *stigmata* of the *Pulmonary Arachnidans*, and especially those of scorpions, are very conspicuous; they occupy the inferior part of the abdomen, and are four in number on either side, (1, 2, 3, 4, *fig.* 84.) They are in the form of narrow fissures, surrounded as in insects with a circle of more solid substance than the rest of the integument, and to which we have given the name of peritrema.

In the spiders (araneæ) not only do they differ in form but in number and position. Treviranus counts four pairs in the thorax above the insertion of the legs, four pairs on the upper part of the abdomen, and one pair on the lower surface; the latter is the most constant and important, (*fig.* 100, *d.*)

The stigmata of the *Tracheary Arachnidans* are less easy to be distinguished, more especially on account of the small size of the species constituting a part of that group. We have here carefully figured them in an Acaroid species (*Ixodes Erinacei*), where they are situated below the sides and on the lower part of the abdomen, (*fig.* 85, *a*,) in shape like a spherical tubercle, (*fig.* 86, *a*,) perforated by

* Annales du Musèum, tom. viii. p. 431. 1806.
† Annales des Sciences Naturelles, first series, tom. ix. pl. 49.

Fig. 84.

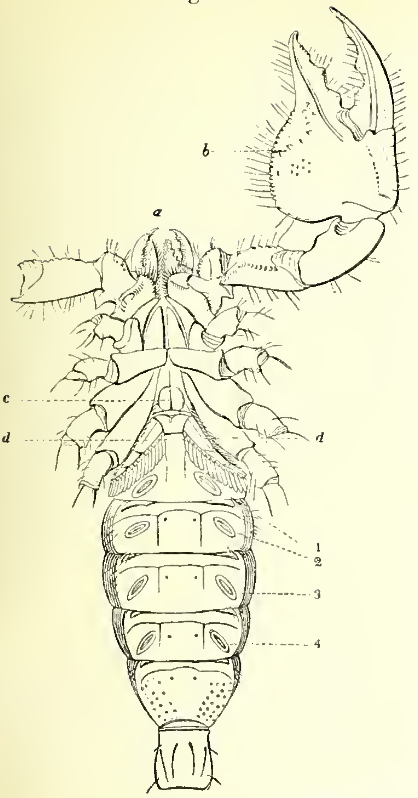


Fig. 85.

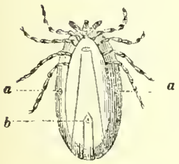
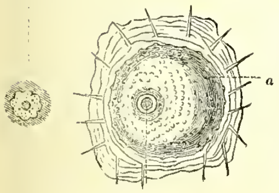


Fig 86.



Ixodes Erinacei.

an infinite number of small holes, between which in the centre we may remark a larger circular plate (*b*.) Each little aperture is as it were stellated at the margins (*c*,) by which the air penetrates the body and gets into the tracheæ. These tracheæ are analogous in structure and position to those of insects; they are elastic, ramify after the manner of vessels in the interior of the body, and penetrate to even the minutest organs.

With regard to the internal respiratory organs of the *Pulmonary Arachnidans* they have a very different character; presenting the appearance of membranous sacs formed by lamellæ applied to one another like the leaves of a book, each of these little receptacles opens into a common cavity, the membranous margins of which adhere to the horny circle or *peritrema* of the stigma before described.

We here subjoin figures copied from those of Professor Müller of Berlin, which represent these parts in a scorpion. *Fig.* 87 shows one of

Fig. 87.

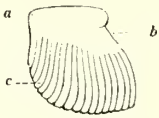
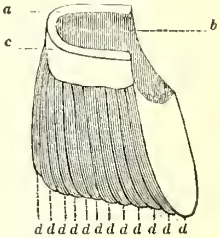


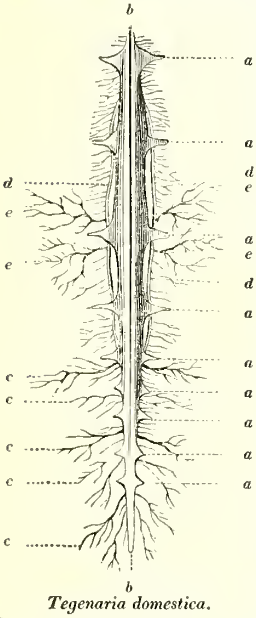
Fig. 88.



the pulmonary branchiæ entire, seen in profile: *a* is the edge by which it adheres to the circumference of the stigma; *b* the simple membrane without folds; *c* the folds or leaves. *Fig.* 88 shows a portion of the same pulmonary *branchia* laid open: *a* is the horny margin of the stigma, or peritrema, to which the simple membrane *b* adheres; *c* the common cavity into which each of the spaces opens which are formed by the laminæ.

These organs resemble closely in their structure the branchial laminæ, and hence Treviranus and Meckel compare them to branchiæ. Müller on the other hand maintains that they are lungs, because, he says, they can be distended with air. The name of pulmonary branchiæ, which we have given them, seems to reconcile the two contending opinions, although we believe that the distinction between lungs and gills is in itself of very slight importance when applied to articulate animals. It is, for example, quite impossible to establish such a distinction in certain crustaceans, as the *Oniscus*, the *Asellus*, the *Cymothoa*, which are all provided with organs of an analogous structure, although some live in water, and others in air more or less humid. Moreover, certain crabs, as the terrestrial species called *Cancer Uca*, *Ruricola*, &c., of Linnæus, possess branchiæ which are much better adapted for respiration in air than in water. The *Cancer Mænas*, so common on our coasts, is almost in the same case, since it passes a great part of its life out of the sea, and it is well known that lobsters and shrimps can live a long time out of water, provided that the air in which they are kept is humid. M. Milne Edwards and myself have demonstrated, by decisive experiments, the conditions in which the branchiæ in these animals act as lungs.

Circulating system.—The function of circulation, which is always so intimately connected with that of respiration, presents, as might be supposed, two different conditions in the *arachnidans*. Those which breathe by means of tracheæ have not an apparent circulation; and in this respect they resemble insects:—we attribute to them simply a dorsal vessel without any ramifications. Those, on the contrary, which possess branchial lungs, have an apparatus for circulation pretty well developed. It consists of an elongated vessel placed immediately beneath the integument along the middle line of the dorsal aspect of the back, on which account it has received the name of dorsal vessel (*fig*. 89). It is kept in its situation by small ligaments or muscles, (*a a*), which in insects are called *alæ cordis*. The texture of the dorsal vessel is membranous, and pretty firm; it contains a colourless fluid. This heart is in communication with numerous vessels, but hitherto it has not been discovered which of these terminate in, or which arise from the organ, or, in other words, it is not known by what route the blood arrives at, or proceeds from the heart. We believe that we are able to dissipate the doubts which still exist as to this subject, but before we state our opinions we shall speak of the anatomical disposition of the apparatus. Treviranus has described it vaguely in the scorpions, but has well elucidated its structure in the spiders (*araneæ*), more particularly in *Clubione atrox* and *Tegenaria domestica*, *Fig*. 89. In both these species numerous vessels are observed to arise from the heart, especially from its posterior part (*c c*.) These proceed to ramify indefinitely, distributing themselves over every organ; and we have no doubt with respect to their true arterial nature. But in addition to these vessels there exist two others of larger size (*d d*,) which communicate in one direction with the heart, in another, by very fine ramifications, with the pulmonary branchiæ. In *Clabione atrox* these two vessels do not give out any branches in their course.



Tegenaria domestica.

No doubt remains in our mind but that these vessels maintain a direct communication between the heart and respiratory organs. The subjoined figure (*fig*. 89) will facilitate the understanding of these facts. It represents the heart and its appendages in the house-spider, (*Tegenaria domestica*,) and shows the two canals which communicate with the heart and receive the small vessels (*e e e e*) that come from the pulmonary branchiæ. Treviranus, to whom we owe these observations, has not, however, attempted to explain the manner in which the circulation takes place in the arachnidans, and indeed this is to be determined by physiological experiment and not by the dissection of the organs merely. The experiments which I have made, in conjunction with my friend M. Milne Edwards, on the circulation of the crustaceans, enable me to give a satisfactory and doubtless true explanation of that of the arachnidans. The organs which exist in these animals, and we admit the precision of the anatomical facts detailed by Treviranus, are essentially the same as in the crustaceans. We find a heart, of the nature of which no one can entertain a doubt: then there are arteries proceeding from the heart and ramifying over every part of the body; lastly, the heart receives on each side vessels which bring it into communication with the respiratory organs. These latter vessels are the analogues of the branchio-cardiac vessels of crustaceans. With respect to veins, of which the latter animals are destitute, they are equally wanting in the arachnidans, and are doubtless replaced by cavities of an irregular form which exist between all the organs of the body. Treviranus, indeed, has remarked in the abdomen of *Tegenaria domestica* two small intervals which are discoverable through the integument, and in which he says the blood may be observed to be collected. These reservoirs are perhaps the analogues of the venous sinuses of the *Crustacea*.

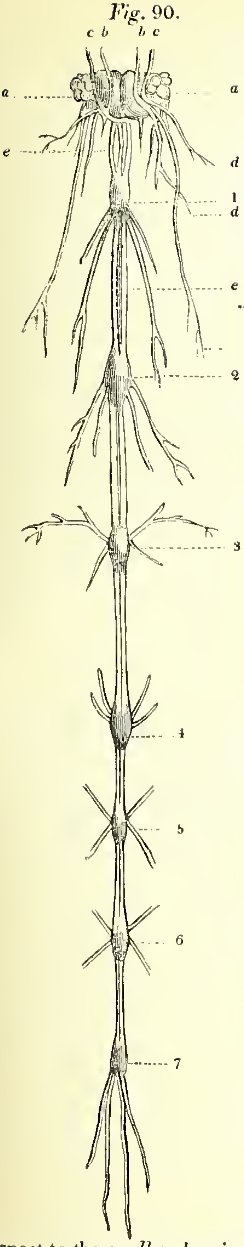
The nature of the vessels being thus determined, it becomes easy to conceive how the circulation takes place in the arachnidans—the blood, leaving the heart, is distributed through all the arteries to the different organs for their nutrition: this being effected, and the nutrient fluid being thereby converted into venous blood, it begins to circulate through the sinuses before mentioned, and arrives by an insensible course at the pulmonary branchiæ. There it is changed by contact with air into arterial blood, and returns to the heart by means of the *branchio-cardiac* vessels (*e d*) to be finally again propelled through the arteries (*c*.)

Thus the ascertained anatomical facts, few as they are, permit us already to appreciate the mode of circulation in the arachnidans; and we repeat that it is in every respect analogous to the circulation in the crustaceans.

Nervous system.—The nervous system is gangliated, as in all the articulate animals: but it presents considerable differences of disposition in the different arachnidans: the scorpions in this respect vary much from the spiders.

In the *Scorpionidæ* we find the following structure (*fig*. 90):—the *first* ganglion, which is commonly called the brain (*a*), and which supplies the nerves to the parts of the mouth (*b*,*c*) is intimately blended with the nervous mass giving origin to the nerves of the legs (*d*). The succeeding ganglia are distinct from one another, and are seven in number: the *first three* (1 2 3) are situated in the abdomen proper; they have this peculiarity, that they are united together and with the ganglion, which may be termed *cerebro-thoracic*, by *three* instead of two chords of communication (*e*), which is the number found in all other articulate animals; the *four* remaining ganglions (4 5 6 7) occupy the entire length of the post-abdomen, or that contracted portion of the body which is incor-

Fig. 90.

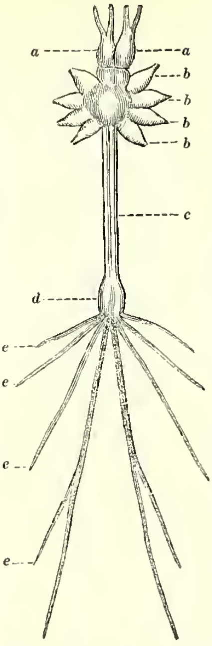


rectly termed the *tail.*

In the *Aranidæ* the ganglions are fewer than in the *Scorpionidæ:* the *first* pair, or that which constitutes the brain, (*fig.* 91, *a,*) is quite distinct from the thoracic; these are *four* in number (*bb*) but have undergone a remarkable degree of centralization, being intimately connected together so as indeed to form a mass in which all traces of junction are lost, except at the sides, which have remained free and in the form of smallconoid bodies directed outwardly so as to resemble, in the aggregate, the figure of a star. From the apex of each of these small cones the nerve is given off to each leg. In the abdomen there does not exist any ganglion, but only a double longitudinal nervous cord (*c*), which swells out at its termination. From this swelling (*d*) a great number of nerves (*ee*) pass off, which are distributed to all the organs contained in the abdominal cavity.

Organs of sense.—We have nothing particular to observe with respect to the *smell* or *hearing* of the arachnidans, for we are ignorant of the existence of these senses in the class, or at least of the parts of the body in which they are seated. With regard to *taste,* the choice which the arachnidans make of their food sufficiently indicates that it exists in variable degree; the organ is situated probably at the entrance of the pharynx. With regard to *touch,* the delicacy of that sense is in the ratio of the tenuity of the integument; but the extremities of the legs, and more especially of the maxillary palps seem to be expressly destined to bring the individual

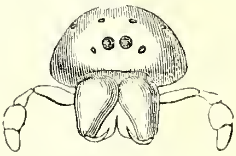
Fig. 91.



into relation with surrounding objects. The sense of *sight* is the only one respecting which no doubt can exist; particularly in the species which are the most perfect of the class, such as the spiders, scorpions, &c. The eyes belong to that kind which are termed *simple,* in opposition to those denominated *compound,* and which are found exclusively in insects and crustaceans.

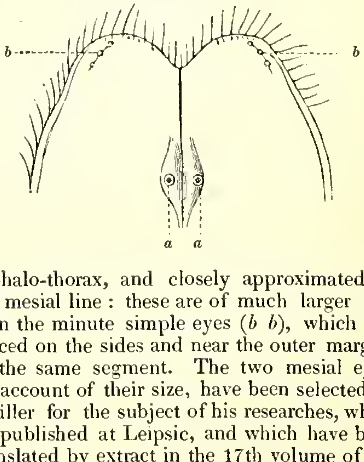
These simple eyes (*ocelli*) in arachnidans are *two, four, six,* or *eight* in number; they are situated on the anterior part of the body either superiorly or laterally. With respect to size they differ not only in different species, but in the same individual, as in the *Platyscelum,* (*fig.* 92,) and especially in the *Attus.*

Fig 92.



In the Scorpions (*fig.* 93) there are *two* eyes (*a a*) situated on the dorsal aspect of the

Fig. 93.

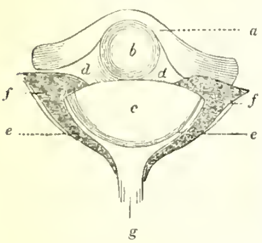


cephalo-thorax, and closely approximated to the mesial line: these are of much larger size than the minute simple eyes (*b b*), which are placed on the sides and near the outer margins of the same segment. The two mesial eyes, on account of their size, have been selected by Müller for the subject of his researches, which he published at Leipsic, and which have been translated by extract in the 17th volume of the first series of the "Annales des Sciences Naturelles." The following are the principal results of the labours of this accomplished naturalist.

He finds that each of these simple eyes is composed, 1st, of a *cornea;* 2dly, of a *crystalline lens;* 3dly, of a *vitreous body;* 4thly, of a kind of *chamber;* 5thly, of a *choroid;* 6thly, of a *retina.*

The cornea, as is shewn in *fig.* 94, which represents a vertical section of the eye, is smooth and convex externally (*a*,) its superficies presenting none of those divisions which characterize the cornea of the compound eyes of insects. The internal surface is deeply concave, and in the hollow hemisphere thus formed is lodged the anterior part of the crystalline lens. This body (*b*) is of a spherical figure, of a hard and transparent texture, resembling in these respects the crystalline lens of Fishes. Posteriorly it rests upon but does not penetrate the vitreous humour. The vitreous humour (*c*) is composed of a granular, soft material, is larger than the chrystalline, plano-convex anteriorly, wholly convex behind. As the crystalline lens rests upon without sinking into the vitreous humour, there remains a circular channel or space filled with an aqueous humour, to which the term chamber may be appropriately given, and which may be compared to the posterior chamber of the eye of some of the vertebrata.

Fig. 94.

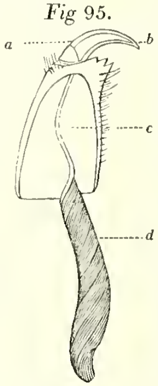


The retina (*e*) is applied to the back part of the vitreous humour, and is in some degree an expansion of the optic nerve (*g*). It is lined by a choroid, or membrane saturated with a coloured matter, or kind of pigmentum (*f*), which is afterwards reflected over the anterior margin of the plano-convex surface of the vitreous humour so as to form there a sort of pupil, the aperture of which exceeds the diameter of the crystalline, but is less than that of the vitreous humour. Such is the somewhat complicated structure of one of the large eyes of a scorpion, by the knowledge of which physiologists are now enabled better to understand the mode in which vision is effected in the arachnidans.

Organs of secretion.—We designate thus the organs that emit outwardly a matter which is sometimes liquid, and sometimes becomes concrete by contact with the atmosphere. The position of these organs varies; in one case they occupy the anterior part of the body, in another they are observed at the opposite extremity. The nature and properties of the matter secreted is not less variable; in some instances it is an irritating or poisonous liquid which the animal introduces by means of a more or less sharp pointed hook into the interior of the body to which it may be applied; in other instances, again, it is a substance which is at first in a liquid state, but soon becomes solid in its passage through a sort of sieve, or, if I may be permitted the comparison, a cullender pierced with excessively minute holes. We shall treat separately of these two kinds of apparatus.

Of the apparatus for secreting the irritating or poisonous liquid.—Every one knows how quickly a fly that has been bitten by a spider expires: the effect is instantaneous. It is by means of the mandibulæ or forciples that the spider has inflicted the wound. These mandibulæ are each armed with a moveable and extremely sharp claw, (*fig.* 95, *a*,) near to the point of which is a minute orifice (*b*), from which there escapes a drop of poisonous liquid, which spreads itself over the whole wound the instant that it is inflicted. This orifice, which from its minuteness is very difficult to be perceived even with a high magnifying power, communicates with a fine or narrow excretory canal (*c*), situated in the interior of the mandible and given off from the true secreting organ. This gland is lodged in the interspace of the muscles of the thorax; it is in the form of an elongated and slightly curved vesicle, the parietes of which have a singular structure. Treviranus describes it as consisting of filaments adhering together and united by a membrane so as to resemble a spirally disposed band. This structure presents, he thinks, some analogy to that of the trachea of insects. Lyonnet, in his posthumous work, has described this part somewhat differently: he considers each little band as being composed of two substances, one fleshy, which contracts upon drying, the other squamous, which is disposed like a watch-spring, or rather like Archimedes' screw, and which always remains in the same state. He supposes that these fibres, upon contracting, force the poisonous liquid into the excretory canal. Such a construction is not, however, necessary, since it may be readily conceived that that vesicle, being placed in the midst of very powerful muscles, it is sufficient that they contract in order to its compression and the consequent propulsion of the fluid contained in its interior, which probably the parietes have secreted.

Fig 95.



This apparatus appears to us to correspond, by its position, to that which is termed, in insects, the salivary apparatus, and in silk-worms the silk-glands: it is even possible that the poisonous fluid itself, mingling with the animal juices which the spider introduces by suction into its stomach, serves to facilitate digestion.

Spiders are not the only animals of their class that are provided with this kind of organs. Scorpions have also a poison-apparatus, but in a very different position. It is not placed in the mandibles, but at the posterior part of the body, in the last segment of the tail-like abdomen. Every one is familiar with that pyriform dilatation which the scorpions carry at the end of the tail; it is terminated by a little sharp hook generally curved backwards. Near its termination there may be observed, as in the mandibulous hook of spiders, a very minute orifice, or, according to some authors, two distinct fissures. It is from this part that a limpid fluid, having strongly-marked poisonous qualities, exudes; and, corresponding to the foramen within, there is the neck of a little bladder which is the true secretory organ. Little is known respecting its structure: according to the observations of Treviranus it is surrounded by a horny substance and provided with a muscle, which most probably has for its function the compression of the vesicle and the consequent expulsion of the poison.

Apparatus for secreting the fluid which concretes in the air.—This apparatus is peculiar to certain arachnidans: it does not exist in the scorpions nor in many other genera; but when present it is always situated at the posterior part of the body. The threads by which the spiders suspend themselves, and of which they spin their webs, are emitted from the extremity of the abdomen. There we find, in the vicinity of the anal aperture, several small appendages, which it is important not to confound with one another, (*fig.* 96.) Of these there are two which are small articulated hairy and filiform processes (*b b*;)* the others are *spinnarets*, or the organs by which the silky threads are emitted. Of the latter, four may generally be counted, (*c d.*) Their structure is very remarkable; it has been described by many anatomists, and among others by Lyonnet in his posthumous Memoirs. This patient anatomist has discovered that the surface of each of the spinnarets is pierced by an infinite number of minute holes, from each of which there escapes as many little drops of a liquid, which, becoming dry the moment it is in contact with the air, forms so many delicate threads. Immediately after the filaments have passed out of the pores of the spinnaret, they unite first together, and then with those of the neighbouring spinnarets to form a common thread; so that the thread of the spider, as it is employed in the manufacture of the web, or such as the creature suspends itself by when hanging from one's finger, is composed of an immense number of minute filaments, perhaps many thousands, of such extreme tenuity that the eye cannot detect them, until they are all twisted together into the working thread. Lyonnet has made a still more curious observation: he detected in *Tegenaria civilis* (Walck.) a different anatomical structure of the four spinnarets. The pair which is above and a little longer than the other, presents on its surface a multitude of small perforations, (*fig.* 97,) the edges of which do not project, and which, therefore, resemble a sieve. This structure has also been well described by Leuwenhoeck, Roesel, Treviranus, &c. The other pair, shorter and lower than the preceding, differs still further by having projecting or mamillary tubes independent of the perforations which also exist and are analogous to those above described. The tubes are hollow, and perforated at the extremity (*fig.* 98, *a*). Lyonnet supposes that agglutinating threads issue from these tubes, while those which are emitted from the perforations do not possess that property. We may observe, indeed, upon throwing a little dust on a spider's web, such as the circular one of *aranea diadema*, that it adheres to the threads which are spirally disposed, but not to those that radiate from the centre to the circumference; the latter are also stronger than the others.

Fig. 96.

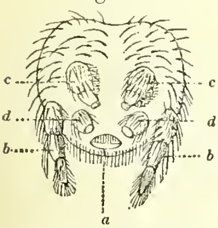


Fig. 97.

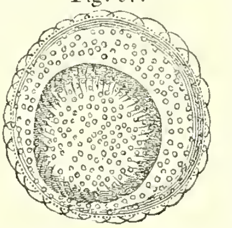


Fig. 98.

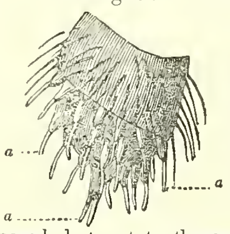
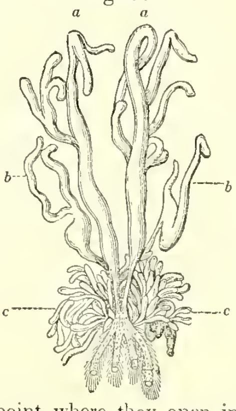


Fig. 99.



Internally there exists in the abdomen of spiders a special secretory apparatus, which consists of intestiniform canals, united together, and variable in number and extent according to the species. In *Clubione atrox*, they consist, according to Treviranus, of four vessels, two large (*fig.* 99, *a a*) and two small (*b b*); near their base, and not far from the point where they open into the spinnarets, a number of small supplementary canals (*c c*) may be observed. (*Fig.* 96 represents the spinnarets in the same species.)

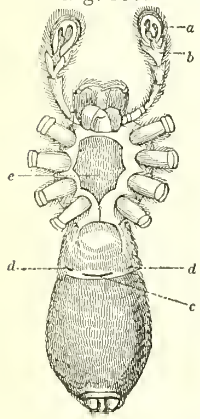
Generative system.—In the arachnidans the sexes are placed, as in insects, in different individuals. It is not always an easy matter to distinguish outwardly the male from the female;

* Mr. Blackwall, who has published some interesting observations on the structure and functions of spiders in the third report of the British Association (1833), and more at length in a recent volume of the Linnæan Transactions, considers these processes to be also spinnarets. They are provided with tubes, which, arranged along the under side of the terminal joint, present the appearance of fine hairs projecting from it at right angles; if examined, when in operation, by a powerful magnifier, the function of these tubes may be ascertained without difficulty, as the fine lines of silk proceeding from them will be distinctly perceived. Mr. B.'s observations were made on *Agelena labyrinthica* (Walck.)—Ed.

but in some cases there exists a well-marked character. The greater part of the araneæ of the male sex have, at the extremity of their maxillary palp, a swelling containing a complicated structure, which is not found in the female. Until lately this protuberance was considered, notwithstanding its anomalous position, as the penis of the male; and even now this opinion is maintained by many naturalists. All observers indeed, both ancient and modern, agree in stating that copulation takes place by means of this part. They have repeatedly observed the fact, and have described the process with all the details that can inspire confidence in their observations. Nevertheless it appears to us certain, if the anatomical facts we are about to disclose are accurate, that there is some mistake on their part, and that what they have taken for the act of copulation was in reality only a prelude to it. It is indeed true th t the male spiders are distinguished from the females by the swelling at the extremity of the maxillary palp, and that that swelling presents a very complicated structure. Treviranus, Savigny, and, earlier than these, Lyonnet, have given detailed figures of it, which may be consulted with advantage: our description will be after that of Treviranus, and from observations made on the common spider, *Tegenaria domestica*.

The male of this species, when arrived at the adult state, presents a considerable dilatation at the extremity of its maxillary palp (*fig.* 100, *a*). On carefully observing this swelling, it is perceived to arise from the penultimate joint (*b*), which is enlarged and spiny. The swelling itself, or what has been termed penis, (*fig.* 100 and *fig.* 101, *a*,) is a concave body from which a membranous, vesicular, and glandiform body (*c*) protrudes, terminated by several horny pieces (*d*), which are curved and project but slightly in this species, but acquire, in others, a considerable development, and protrude in the form of long hooks having a much greater complication of structure.

Fig. 100.



In order that this part should be a penis, as has been supposed, and as many naturalists still believe, it ought to be perforated for the emission of the prolific liquor. Now, Treviranus is certain that it is not perforated by any foramen, and also that there does not exist in the interior of the palp any excretory duct which could have brought to this part the secretion of the testicles. Lastly, and this proof is still more conclusive, on examining carefully the under surface of the abdomen of a male, he discovered at its base, i. e. at the point where it is inserted into the thorax, between the apertures of respiration, and at the part corresponding to the vulvary opening of the female, two very small orifices, placed in a transverse fissure, which he ascertained to be the true outlets of the male apparatus. He found in the interior of the abdomen two cylindrical dilated vessels, which he determined to be the testes. (*Fig.* 102, *b*, *b*.) These two organs open into two long, slender, tortuous, excretory canals (*c*), which terminate at the two orifices of which we have spoken (*a*), but without the appearance of any superaddition of a firm or horny part that can be compared to a penis. From this description it is certain that what has been regarded as the act of copulation, has been only preliminary, and that the introduction of the extremity of the maxillary palp of the male into the vaginal apertures of the female was for the mere purpose of opening the oviducts in order that the actual coitus should be effected with facility and without doubt instantaneously; which explains why no observer has hitherto witnessed the act.*

Fig. 101.

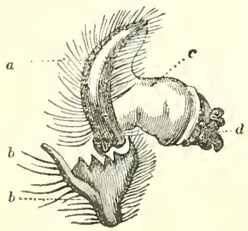
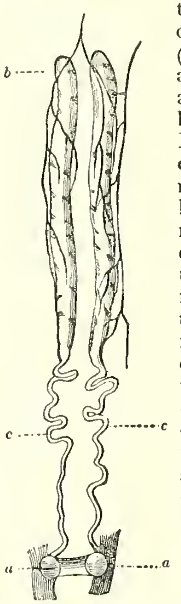


Fig. 102.



The remarkable sexual differences which obtain in the araneæ are not found in other arachnidans. Thus in the scorpions the maxillary palps have a similar organization in both sexes, being terminated by pincers, both in the male and female, (*fig.* 84, *b*.)

The external aperture of the male apparatus is placed behind the thorax, and manifests itself by the presence of a valve formed by two semicircular pieces (*fig.* 84, *c*.) The internal structure of these organs is but imperfectly known. Treviranus believes that he could distinguish the testicles which terminated at the extremity in a kind of horny penis. Leon Dufour has given a more detailed description of these organs, together with a figure which represents each testis, as being a large network of three meshes formed by cylindrical tubes.

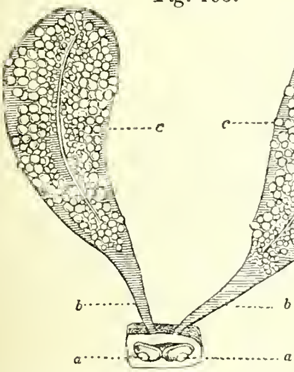
The male, like the female scorpion, presents at the inferior part of the body on either side of

* Mr. Blackwall denies the accuracy of Treviranus's opinion, and supports that of Lister and the older observers, as to the sexual function of the maxillary palp, founding his remarks on observations made on various individuals of the genera, *Epeira*, *Theridion*, and *Agelena*. We must refer for the details to the memoir before quoted from the Transactions of the Linnæan Society.—ED.

the valve certain organs of a singular structure which are called combs, *pectines*, (*fig.* 84, *d*,) on account of the disposition of a series of small appendages of which they are formed, and which are arranged on the lower surface one beside the other, like the teeth of a comb. Many speculations have been offered respecting their uses. Many naturalists believe that they render some assistance in the act of impregnation. Some suppose that they are extended during progression, and prevent the abdomen of the scorpion from trailing on the ground: others, again, regard them as hygrometrical organs, by means of which the animal judges of the humidity of the atmosphere. These are, however, all mere gratuitous hypotheses unsupported by any observation; and the fact is that we have yet to learn the use of these pectinated appendages.

Of the female generative system.—It has been long known that the orifices of the generative organs in female spiders are situated at the base of the abdomen. We observe on that part of the body two distinct cavities, (*fig.* 103, *a, a*,) which are closed by opercular pieces of

Fig. 103.



a more or less solid texture, and it is at this part that the oviducts terminate. In the *tegenaria domestica*, these oviducts (*b, b*) are continued internally in an insensible manner with the ovaries, which consist of a kind of bags (*c, c*) situated on each side of the intestinal canal, and to whose parietes the ova are attached in a racemose manner. In the *epeira diadema* the ovaries are divided by two longitudinal membranous septa, and each is again subdivided by a transverse septum. The longitudinal septum has no orifice, but the transverse one is perforated. There is, therefore, no communication between the principal chambers of each of these ovaries, but there is a passage from the anterior to the posterior division, and the ova which are in the former must pass into the latter before being extruded. This structure explains how it happens that the *epeira diadema* lays its eggs at two distinct periods. Another spider (*theridion quadripunctatum*, Walck.) presents a very analogous organization.

The female generative apparatus of scorpions has not hitherto been studied with that degree of care which it deserves; and there is a considerable difference among authors with respect to this subject; it therefore requires farther examination. Treviranus and Leon Dufour have described these organs as consisting of three elongated tubes; of these, two are lateral and mutually communicate at their apices, the third is mesial and communicates with the lateral by three branches which we observe on either side. All of them, lastly, terminate at the vaginal orifice which is concealed by a more or less rounded plate, and is situated on the middle line of the body anterior to the pectines and between the coxæ of the fourth pair of legs, at the same point where the penis is placed in the male (*fig.* 84, *c*.)

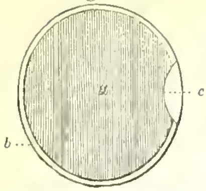
Copulation, oviposition, and development of the ova. Metamorphosis, and reproduction of the extremities.—Natural observers have hitherto given but very few details respecting the manner in which the male spider approaches the female, in accomplishing the sexual act: and we have already observed that they have been deceived in considering a preliminary step as the entire process. The preliminaries are accompanied with very curious circumstances, the account of which may be found in all the memoirs and works which treat of the animals of this class. It will be there seen with what precaution and fear the male makes his approaches to the female, who is always ready to attack and devour him, whether before or after copulation. The majority of the arachnidans deposit their eggs in great numbers. The female guards them with the utmost care, sometimes carries them about with her, and always prepares a silken nest for them which is frequently covered with a solid exterior. Some arachnidans, as the scorpions for example, are ovo-viviparous; the ova are developed in the interior of the body of the female who brings forth her young possessing the faculty of locomotion; but they rest for a certain time attached to the back of the mother, who guards and feeds them, and gives them a kind of education.

The changes which occur in the ova of spiders (araneæ) have been studied with much care. We are indebted to M. Heroldt for highly interesting observations on this subject, published in the work entitled "Exercitationes de animalium vertebris carentium in ovo formatione," folio, Marburg, 1824, from which an extract is given in the Annales des Sciences Naturelles, first series, vol. xiii. p. 250. From the importance of these researches we here present an analysis of them.

The exterior covering of the ovum is formed by a very delicate and transparent membrane, in the composition of which no pore or fibre can be distinguished on microscopical inspection.

Within this membrane there is a liquid matter in which Heroldt has distinguished several essential parts, which in relation to their functions appear to us to correspond to the *vitellus*, the *albumen*, and the *cicatricula* of the egg in birds. An idea of the disposition and size of these parts may be formed by inspecting the subjoined figure (*fig.* 104),

Fig. 104.

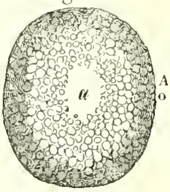


representing a vertical section of a fecundated ovum at the moment of exclusion, and before any organ has been developed. The *vitellus* or yolk (*a*) forms the greatest part of the contained liquid matter, and the egg is almost entirely filled by it: its colour is generally that of yellow ochre, and sometimes has a saffron tinge. In some species the yolk is grey, white, or reddish brown; and in each case the colour of this part determines the general tint of the egg. If the yolk be considerably magnified, it is seen to be composed of an infinite number of minute globules of various sizes, swimming in the albumen, or surrounded by it, and resembling so many small yolks.

The *albumen* (*b*) is a transparent crystalline liquid, without distinct organical parts, and consequently not presenting any globules, surrounding the vitellus as far as the cicatricula, and intermediate in bulk or quantity to these. If an ovum be opened, and the liquid which it contains be poured out upon glass, the albumen is seen to surround the globules of the vitellus and cicatricula exactly as the serum of the blood envelopes the crassamentum. In the interior of the egg the albumen is situated, like the cicatricula, externally to the yolk, and fills the interspace between the yolk and the exterior membrane of the egg. It is in this interspace that the first lineaments of the embryo appear, and here the head, thorax, members, integuments, and their appendages, and all the internal organs, without excepting the intestines, are successively developed.

The *cicatricula* or *germ* (*c*) is the smallest and most important part of the ovum. It is situated immediately beneath the exterior covering, and at the centre of the circumferenee of the egg. It is distinguished by the naked eye in the form of a little white point. If it be examined with more care, we perceive that it is of a lenticular figure, and is composed of an innumerable quantity of whitish granules. Under the microscope these granules are seen to be of a globular figure, somewhat similar in this respect to those of the yolk, but more opake, and of a smaller diameter. When segregated and diffused they present a striking analogy to the grains of pollen, but with this difference, that the pollen of vegetables is composed of vesicles filled with organic molecules, whilst each of these globules of the cicatricula must be regarded as simple. The cicatricula or germ is the centre of radiation of all the changes which take place in the ovum. All the parts which it contains seem subordinate to it, as we shall see by carefully tracing their development. A remarkable fact observed by Heroldt in the ova of some undetermined species of spiders is this, that in place of a single cicatricula, there appear to be several spread over different points of the surface of the ovum; but these small germs rapidly coalesce into one mass, which soon assumes the ordinary form of the single cicatricula. The component parts of the ovum being known, we proceed to the metamorphoses which they undergo up to the time when the young spider breaks through the shell.

Fig. 105.

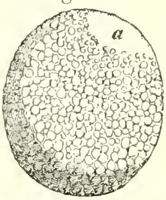


First period.—The impregnated ovum being deposited, and the temperature being favourable, development commences. The changes always begin at the margins of the cicatricula, which appear to be resolved into granules, which extend into the albumen and vitellus. The centre of the germ remains the same, the only appreciable difference is the enlargement of its circumference: (A, gives the natural size of the ovum.)

Second period.—The germ is much larger, its margins are dispersed in numerous granules; the centre is not yet affected by this tendency to molecular dispersion, but has undergone a notable modification. It changes its situation and begins to move towards the extremity of the ovum, leaving in the place which it formerly occupied a train of globules; it now, to compare small things with great, bears some resemblance to a comet, the nucleus of which is represented by the centre of the germ; the tail, which is formed by the dispersion of the globules, is transparent, and the vitellus which it covers may be as distinctly seen through it as the fixed stars through the tail of a comet.

Third period.—The nucleus of the germ (*fig.* 106, *a*), which has continued to change its place, is arrived near the extremity of the ovum, but has not quite reached it. The tract which it has traversed is marked by an infinity of granules, which are then so much disseminated that they extend almost to the opposite extremity of the ovum. It is then that the kind of comet which it represents is seen at its greatest development, and with all the characters that have been indicated. The movement of the nucleus of the cicatricula authorizes the supposition that that body has not, at least at the earlier periods, a very intimate connexion with the vitellus.

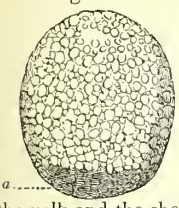
Fig. 106.



Fourth period.—The nucleus of the germ has not gone beyond the point which it had attained, but it presents a new change. The molecules are disseminated into an infinity of granules, nothing remains of the comet but the tail, which is still more extended; but we see then that the granules dispersed in the albumen have a tendency to reassemble at the point where the germ was originally situated.

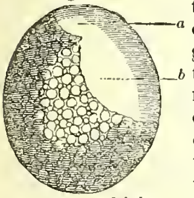
Fifth period.—The germ of the ovum, which appears to be disseminated in the albumen, has undergone a very curious transformation. Its nucleus has disappeared, all its granules are decomposed into almost imperceptible molecules, which, in destroying the limpidity of the albumen, have given it a clouded appearance, through which, however, the globules of the vitellus may be distinguished. A single point remains perfectly transparent, and this is observed at the extremity of the egg (*fig.* 107, *a*,) opposite to that which the germ occupied after its displacement. Heroldt calls this clouded albumen *colliquamentum*. Up to this period the vitellus seems not to undergo any change; all that has been hitherto observed takes place in the albumen and in the circular space between the yolk and the shell.

Fig. 107.



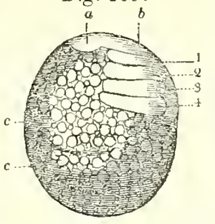
Sixth period. — The colliquamentum, or clouded albumen, which was extended over the yolk so as to conceal it, is now concentrated upon the point last occupied by the nucleus of the germ, and has assumed a pearly colour (*fig.* 108). Its consistence is pretty solid; it is opake, so that the globules of the yolk can no longer be distinguished through it, although they are elsewhere more conspicuous on account of the retreat of the clouded albumen towards this single point; from this moment the colliquamentum, which seems to have changed its nature, receives a new name, and is designated by Heroldt the *cambium*. The cambium covers more than a fourth part of the circumference of the yolk; its form is already pretty well marked, and two parts may be distinguished in it; one large (*b*), the other small (*a*), which are separated by a kind of contraction. The form of the larger division is elliptical, and it is in its substance that the thorax, the legs, and the essential internal parts of the fœtus will soon be perceived to develope themselves. The smaller division is of a rounded form, and seems, as it were, an appendage to the preceding; it is destined to give origin to the head, the organs of sense, and the appendages of those of mastication. So much being premised, we may call, with Heroldt, the larger division *cambium thoracicum*, the lesser one *cambium cephalicum*. We may also, for the better comprehension of the changes which are about to succeed each other, divide the superficies of the ovum into four regions. That which contains the cambium may be called the *pectoral* region, the opposite portion may be called the *dorsal*, and the two intermediate parts the *lateral* regions. We may observe that in other species of araneæ where the ova are spherical, the germ is at once converted into colliquamentum, and then into cambium, without a change of situation. The *Aranea diadema* offers an example of this circumstance; in other respects there is no important difference observable.

Fig. 108.



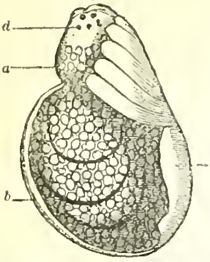
Seventh period.—The two portions of the cambium, the cephalic and thoracic, have as yet presented only the appearance of an opake and homogeneous mass, but now we may distinguish traces of rings, four in number on either side; these are the rudiments of the legs. (*Fig.* 109, 1, 2, 3, 4.) They occupy the lateral aspects of the anterior part of the ovum; they are also visible on the pectoral region, towards which they are prolonged inferiorly. The extremity of the first leg is contiguous to that of the opposite side; but the three others, though of greater length, yet do not reach so low down, but leave a triangular interspace between them, which is filled with a cloudy and somewhat transparent matter, through which the vitelline globules are visible. This triangular space, which is subsequently to be covered by the legs, seems to give origin to the trunk and to many parts contained in the abdomen. In tracing the two portions of the cambium through the changes which they have undergone, we find that the thoracic portion is represented by the legs and their intermediate space, and that the cephalic portion is anterior to this. The alterations of the latter part are not less remarkable; instead of being rounded anteriorly it is truncated, and we may perceive a ring at the sides, which is not divided on the inferior middle line of the body, and which represents the maxillary palps (*b*). One may even distinguish, as if through a cloud, the rudiments of the mandibles. It is probable that all the parts which appertain to the head, as the eyes, the mandibular hooks, and the maxillæ, have their limits well defined from this period. With respect to the head, (*a*) it is neatly separated from the chest; and this fact it is of importance to dwell on, since in all the full-grown spiders the confluence of the two parts is most intimate, and their original separation only indicated by a groove of greater or less depth. The ovum, also, now presents some other new appearances; these are a kind of furrows or arched folds (*c c*), which are seen on the vitellus behind the legs; and which deserve attention, since they indicate the formation of the common teguments of the fœtus. And we must here observe that the parts which are already developed have an intimate connection with the vitellus. Thus if an ovum be opened with all the precautions requisite for so delicate an operation, and if the matter of it be extended on a piece of glass, we see that the parts formed in the cambium preserve their general figure, and that the internal layer of the mucous and whitish matter of which it consists is in intimate communication with the vitellus. It is implanted upon the yolk just as fungi and other parasitic plants are attached to the trunk of a tree: the yolk, then, is subservient to the nutrition of the most exterior parts of the body.

Fig. 109.



Eighth period.—The exterior parts which are developed in the cambium, viz. the feet, the mandibles, and the head, are more neatly defined. The ovum (*fig.* 110) now presents a

Fig. 110.



very important peculiarity, but which was in some measure indicated in the preceding period. Its size is slightly diminished anteriorly, and the vitellus consequently is divided into two portions. The smaller and anterior part *(a)* is readily distinguishable from the dorsal part of the fœtus, and occupies the place which subsequently becomes that of the corslet; M. Heroldt consequently terms it the *thoracic region*. The other part is the *abdominal region*, which is very conspicuous, occupies more than one-half the bulk of the ovum, and seems to constitute the greatest portion of the abdomen. If the inferior surface of the abdominal region be examined, there will be seen, in addition to a spot which ornaments that part, some additional oblique and curved folds, which indicate the formation of the integuments; another and a more important change has now taken place on the middle line of the superior surface; viz. an obscure straight band *(b)* which commences at the thoracic-abdominal constriction, and reaches to the extremity of the ovum, becoming gradually narrower in that direction. This band, which does not give off lateral processes in any part of its course, is to be considered as the rudiment of the heart or dorsal vessel. The fluid which it doubtless contains in its interior is motionless. Heroldt thinks that the formation of the fluid is anterior to that of the parietes in which it is enclosed: he also believes that it is the albumen which gives origin to the circulatory apparatus, and further attributes to it the origin of all the integuments. These are, doubtless, important questions to solve, but as they are the result of speculation rather than direct observation, we have deemed it proper to omit the theories by which they are supported, and confine ourselves to a simple enunciation of the facts The eyes *(d)* are now distinguishable.

Ninth period.—The ovum presents a more sensible diminution anteriorly, and is more distinctly divisible into two parts. The anterior and narrow portion constitutes the smaller extremity, and includes the head, the thorax, and their appendages; the other portion, which is spherical and of much larger size, constitutes the greater extremity and corresponds to the abdomen. At the same time that these modifications take place the ovum becomes slightly elongated, and all the parts which can be distinguished therein have proceeded towards their perfection. The legs now present slight traces of a division into joints, and they have increased so far in length that they cover almost the whole of the lower surface of the thorax.

Tenth period.—The small extremity, which is still more elongated, is now found to be distinguished from the large one by a true constriction, dividing the ovum into the parts denominated in the perfect spider 'thorax' and 'abdomen.' The visible parts of the thorax are the mandibles, the palpi, and the legs; these latter appendages are folded upon the chest, and have grown so long as to cross the middle line of the body; they are locked in the interspaces of each other, like the fingers when the hands are clasped together. The abdomen presents nothing remarkable, except the elongated opake streak which exists along the middle of the inferior surface from the feet to the termination of the abdomen, and which was already visible at the preceding periods. (*Fig.* 110, *e.*) Heroldt imagines this streak to be an indication of the development of the internal parts of the abdomen, viz. the intestinal canal, the secreting vessels of the web, and the genital organs, &c. In proportion as the fœtus increases, the external membrane or covering of the egg is applied more exactly to its body, and seems to represent an exterior skin, of which the young spider soon divests itself, almost in the same manner as the caterpillar sheds the skin in which it is enveloped.

Eleventh period.—By the progressive increase of the fœtus the membrane of the egg becomes so much stretched, and is applied so exactly to the surface of the body of the animal that the different parts can be distinctly seen through it, like the nymph or chrysalis of certain coleopterous insects. The essential parts of the thorax are the head and the feet. The head is of a white colour, and is surmounted by eight brown streaks; the legs, which are also white, are closely applied to the chest, with their extremities alternating with each other. One may distinguish in each a hip, a thigh, a leg, and a tarsus. The articulations of the palps and mandibles are also visible through the general envelope of the egg. The inferior streak of the abdomen is much more extended, and seems to be divided into two parts, one large and elliptical in figure, the other small and rounded; the latter corresponds to the anal aperture; at this last stage of the development, the fœtus or the imprisoned young spider, as it may be called, gives no sign of motion.

Exclusion or hatching of the spider.—At length the spider bursts the egg by tearing through the exterior membrane. De-Geer* has described this phenomenon. The outer membrane or pellicle of the ovum becomes fissured along the corslet, and the spider protrudes by this aperture, first the head, the mandibles, the thorax, and abdomen, after which there remains the more difficult operation of extracting the legs and maxillary palps from that part of the outer membrane with which these parts are, as it were, enveloped. This is at length effected, though slowly, by alternately dilating and contracting the body and legs, upon which the animal is liberated, and capable of progression. In proportion as the parts are disengaged from the pellicle, it is pushed towards the extremity of the legs, and is reduced to a little white bag which is all that remains. Sometimes the pellicle is found still slightly adherent to the ab-

* Mém. sur les Insectes, t. vii. p. 195.

domen, but the spider soon entirely frees itself from it. This is the mode in which the young spiders of every species disembarrass themselves of the egg-covering, and the operation is analogous to that of moulting. This is, however, only the first birth: all the parts of the spider, the head, the jaws, the legs, the abdomen, are still enveloped by a membrane which furnishes to each a sort of sheath. The spider is embarrassed in all its movements; it changes its situation with apparent pain, and is unable to construct a web and seize its prey: it seems indeed to be stupified and indisposed to action. To this end, and in order to be fit for locomotion, it is necessary that it should free itself of this other covering; and it is only then that it can be said to see the light. This last operation, or as it may be termed the first moult, takes place after a period, varying according to the degrees of atmospheric heat and moisture. Sometimes it is observed within the first week, at others it is not effected before the end of several weeks. In every instance the moult takes place in the woolly nest or general envelope of all the eggs, and the young spider does not quit this common nest, except in fine weather, generally in the months of May and June.

Before arriving at the adult state the spider changes its skin many times, and even after that period it is still subject to moults, which occur every year in the spring, and after the exclusion of the eggs. Up to the present time it has been admitted that the Arachnidans, from the moment of their exclusion to their adult state, undergo no metamorphosis, but are subject only to the moultings of which we have just spoken. This circumstance has even been employed by zoologists as a character distinguishing the arachnidans from the class of insects, which generally undergo metamorphoses in passing through the conditions of the larva and chrysalis. The observation holds good for the greater part of the Arachnidans, but there are many of this class, which, in passing to their adult condition, undergo changes which cannot but be compared with the metamorphoses of insects. Such, for example, are many of the *acaridæ*, upon which M. Dugès has recently fixed the attention of naturalists.*

We cannot conclude the present article, without briefly noticing a very curious physiological phenomenon which has been observed in the Arachnidans, and which has long been noticed in the class Crustacea: we allude to the faculty which these animals possess of reproducing their limbs when these have been accidentally lost. This property, which belongs to the spiders, (*araneæ*,) was generally doubted, until a distinguished naturalist, M. Lepelletier, published the result of his experiments; the fact is of too much importance in science not to be dwelt upon with some detail. Spiders which have lost a limb, according to this observer,† are always found to have lost it entirely, that is, the femur, tibia, and tarsus, are all wanting. A portion of a leg is never found detached at one of its joints, nor broken off between two joints, nor the femur remaining adherent to the body by itself, or with the tibia, the rest of the leg being lost. If by accident a spider should be met with in any of these conditions, it is either dying or dead. But M. Lepelletier remarks that those which have lost one or more entire legs, are not less lively on that account.

To explain these circumstances our author commenced a series of experiments on spiders, in the year 1792, with the following results:—

The smallest wound in the thorax or abdomen of a spider is mortal, and that in a very short time, on account of the loss of the internal nutrient fluid, which cannot be staunched.

If a leg of a spider be cut off with a sharp instrument either at one of its joints, or in the interval of two, leaving a part of the limb adhering to the body, the spider appears to suffer considerably; it endeavours to tear off the rest of the leg; if it succeeds, it again acquires its powers of moving, and the hemorrhage soon ceases; in the contrary case it perishes in twenty-four hours.

The luxation of one of the joints, or the fracture of the femur or tibia in the middle are equally mortal, if the spider does not soon disembarrass itself of the leg which has received the injury.

It is necessary here to make a remark upon the anatomy of the legs of spiders and crustaceans; they have the first joint short, which connects the leg to the thorax; M. Lepelletier calls this the haunch, *coxa*. If a spider be seized by the extremity of one of its legs, and is left at liberty to make its efforts to escape, the leg will be separated from the body at the junction of the *femur* with the *coxa*; and the same thing takes place when the body of the spider is held fast, and the leg is pulled off. In both these cases the spider seems not to suffer pain; it experiences only a very little loss of the internal fluid, and does not die in consequence; it spins, seizes its prey, and oviposits in the ordinary manner.

The preceding facts are applicable to all spiders, (*araneæ*,) and M. Lepelletier has observed them repeatedly in many of the common species. The following experiments have been made only on the domestic spider, (*Tegenaria domestica*, Walck.) because it can be preserved in a lively condition, and for many years in a glass vessel.

We have successively observed a great number of individuals of this species which were mutilated of one or more legs. It was not without surprize that the author of this article observed the first spider that was experimented upon, and which wanted a leg, change its skin, and after that operation reappear with eight legs. The like occurrence was frequently observed; the new leg was two or three lines in length when it first appeared, that of the opposite side being less than an inch: each of the joints of the former continued to grow during the whole of the year.

* See his interesting Memoir in the Annales des Sciences, Nouv. Serie, tom i. and ii., 1834.

† See Bulletin de la Societé Philomathique, Paris, Avril, 1813.

The general result of these observations, and of many others of the same kind, is, 1st, that the legs of spiders can be reproduced when they have been torn off; 2d, that this reproduction can only take place when the limb has been detached as high as the moveable base; for otherwise an hemorrhage supervenes which kills the animal; 3d, that the reproduction takes place only at the time of the moult, and that the new leg is at first slender, but with all its parts or joints, each of which increases progressively, until the whole has acquired its natural relative size.*

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(Victor Audouin.)

ARM. (Surgical anatomy.) (The arm, Gr. Βραχιων. Lat. *Brachium*. Fr. *Bras*. Germ. *Oberarm*. Ital. *Braccio*.) The ancients applied this term to the whole of the upper or thoracic extremity collectively, as most persons do in ordinary discourse, at the present day; but in anatomical language the term is restricted to that section of the upper limb included between the shoulder and the elbow. The arm taken in this limited sense is somewhat cylindrical, a little flattened, however, on its internal and external surfaces, particularly towards its middle; it varies much in its proportions as to length and volume: it is more rounded in fat persons, and especially in females, in whom it assumes more or less of a conoid form, tapering towards its lower part. (See *fig.* 1 and 2, p. 3.) The arm is composed of a single bone, the humerus, several muscles, bloodvessels, absorbents, and nerves connected together by cellular tissue, and inclosed in an aponeurosis, which lies immediately beneath the common integuments. Viewing the arm extended, the hand being placed in a state of supination, we observe at its superior and external part a prominence of a triangular form, the base of which is superior; this is formed by the deltoid muscle, and is bounded before and behind by two slight grooves, which unite below in a depression called deltoid fossa, situated immediately over the insertion of the deltoid muscle; this deltoid fossa is the most eligible part of the arm for the insertion of issues, as it contains a considerable quantity of cellular tissue, affording a favourable bed for the reception of peas or other bodies inserted for the purpose of exciting suppuration, while it possesses this additional advantage, that no muscular fibres extend across it, whose contractions might have the effect of deranging the surface of the ulcer or the dressings necessary to be applied to it, and thus causing an unnecessary degree of pain. From the deltoid fossa a superficial depression extends along the outer edge of the arm, and terminates in the triangular fossa in front of the bend of the elbow: along the course of this depression blisters are frequently applied by the Parisian and other continental physicians in inflammatory affections of the thoracic viscera, a mode of treatment not generally employed in such cases by the physicians of this country. Another depression extends along the inner side of the arm from the axilla to the hollow in front of the elbow, where it joins the external depression. Between these two depressions there is an oblong prominence anteriorly, formed by the biceps muscle, and a more flattened prominence intervenes posteriorly, formed by the triceps which occupies the whole of the posterior surface of the arm.

Skin and subcutaneous tissue. — The skin covering the arm is soft and delicate; sebaceous glands and hairs are not very evident on it, especially in front; it is thicker and stronger, however, on the posterior surface. The basilic vein is generally visible at the lower part of the internal brachial depression, and the pulsations of the brachial artery may be felt along the whole of its course: the cephalic vein is sometimes visible, especially in thin persons, along the course of the external brachial depression. As the skin of the arm is loosely connected to the subjacent parts, the edges of simple incised wounds in this region are easily retained in contact. The subcutaneous layer of cellular tissue or superficial fascia contains more or less adipose substance, in greater abundance in women and children than in men, and in greater quantity in the depressions than over the muscular prominences; the filaments

* Mr. Blackwall, in the paper already referred to, has related an accidental discovery of the power of some spiders to abstract respirable air from water. Several individuals have preserved an active state of existence under water for six, fourteen, or twenty-eight days, spinning their lines and exercising their functions as if in air, while others have not survived for a single hour.—Ed.

of the cutaneous nerves of the arm and the superficial veins and absorbents lie imbedded in it: thus the cephalic vein and twigs of the external cutaneous nerve appear along the outer edge of the arm, and along the inner edge are found the internal cutaneous nerve, the brachial branches of the second and third intercostal nerves, the cutaneous nerve which arises from the ulnar high in the axilla, the basilic vein, and a few lymphatic glands, which lie at from one to three inches above the internal condyle.

Aponeurosis. — Beneath the subcutaneous layer of cellular tissue lies the aponeurosis or fascia, which invests the muscles and the deep-seated vessels and nerves of the arm: this fascia commences above at the superior attachment of the deltoid muscle; externally and internally it is continuous with the fascia, which extends over the axillary space; descending along the arm it is strengthened by expansions which it receives from the tendons of the deltoid, pectoralis major, and coraco-brachialis in front; and behind it derives an accession of strength from the aponeurosis which covers the infra-spinatus and teres minor, and from the tendons of the latissimus dorsi and teres major. At the lower part of the arm the fascia is attached to the condyles of the humerus; laterally and posteriorly it is attached to the olecranon, on either side of which it is continuous with the fascia on the posterior surface of the fore-arm. In front of the elbow this fascia receives a fasciculus of fibres from the tendon of the biceps, and becomes continuous with the fascia covering the anterior surface of the fore-arm. The fascia of the arm varies in strength in different parts; it is very indistinct over the deltoid, thin but very fibrous on the posterior surface of the arm where it covers the triceps; it is much stronger over the biceps, and the thickest portion of it is found along the inner edge of the arm, where it covers the brachial artery and its accompanying veins and nerves. A strong aponeurotic septum passes in from the fascia of the arm to each of the lateral ridges of the humerus; these septa are called intermuscular ligaments, and, together with the humerus, divide the space included within the general fascia into an anterior and a posterior sheath; the external intermuscular ligament extends from the insertion of the deltoid to the external condyle; the internal extends from the insertion of the coraco-brachialis to the internal condyle. Both intermuscular ligaments are narrowest above, and grow broader as they approach the condyles: their surfaces give attachment to fibres of the triceps posteriorly and to the brachiæus anticus, supinator radii longus, and extensor carpi radialis anteriorly. The posterior sheath, formed as above described, is chiefly occupied by the triceps muscle, beneath which, in the spiral groove on the posterior surface of the humerus, lie the musculo-spiral or radial nerve and the superior profunda artery: this nerve and the anterior or musculo-spiral branch of the superior profunda artery perforate the external intermuscular ligament and enter the anterior sheath of the arm to get between the brachiæus anticus and supinator radii longus, while the posterior branch of the profunda descends within the posterior sheath to the back part of the external condyle; the ulnar nerve and the inferior profunda artery enter this posterior sheath together at its internal side, about the middle of the arm, and descend within it to the back of the internal condyle. A considerable branch of the brachial artery, the ramus anastomoticus, perforates the internal intermuscular ligament above the internal condyle, and enters the lower part of the posterior brachial sheath. The anterior sheath of the arm contains the biceps, coraco-brachialis, brachiæus anticus, and the origins of the long supinator and long radial extensor muscles; the external cutaneous nerve traverses this sheath, perforating the coraco-brachialis above, and descending obliquely outwards between the brachiæus anticus and the biceps it gets to the outer side of the latter, between the tendon of which and the supinator radii longus it pursues its course to the fore-arm; the radial nerve and the branch of the superior profunda artery accompanying it are to be found in the lower and external part of the anterior sheath, which they enter as above described: these lie deep between the brachiæus anticus and supinator longus. Along the internal side of this anterior sheath, through its whole extent, run the brachial artery, and its two venæ comites included in a sheath proper to them, and accompanied by the median nerve, which has very important relations to these vessels: this nerve is external to the artery above, crosses it in the middle of the arm, and lies internal to it below. Superiorly the ulnar nerve lies to the inner side of the brachial artery, from which it separates to enter the posterior sheath, as already noticed; the internal cutaneous nerve, the cutaneous twig of the ulnar nerve, and the basilic vein for a short part of its course before it enters the brachial vein, also lie within this sheath; and deeply situated in its lower part is the ramus anastomoticus magnus of the brachial artery.

Developement. — In the progressive developement of the upper extremity in the fœtus, the arm is formed subsequently to the hand and fore-arm, and at an earlier period than the shoulder. In men the deltoid is fuller, and the biceps in front and the triceps behind are more prominent than in women: the greater fulness of these two latter muscles, with the smaller quantity of subcutaneous fat, give to the male arm a greater diameter from before backwards than in the transverse direction; while the more slender character of the muscles and the greater abundance of subcutaneous fat laterally cause the arm of the female to assume a more rounded form. In the course of the brachial artery two trunks are often found to exist, in consequence of a high branching of that vessel, which sometimes occurs even at the lower border of the axilla: the supernumerary branch in such cases is most frequently the radial: in some instances it is the ulnar and less frequently the interosseous or median artery of the fore-arm. When this irregularity occurs, the brachial artery usually preserves its ordinary relations to the surrounding parts, while the supernumerary trunk lies to its internal side and takes a more superficial course, sometimes getting above the fascia of the arm, as we have witnessed in a few rare cases. It occasionally happens that the brachial artery divides at its commencement into two trunks, which again unite at its lower part. It is obvious that the surgeon, in performing operations on this artery, should constantly bear in mind that it is subject to the above-mentioned irregularities, and that he should cautiously guard against committing the error of including the wrong vessel in his ligature.

The internal side of the arm in the middle of its length is the most eligible place for making compression on the brachial artery; here this vessel is superficial, so that its pulsation can be felt at once, whilst it has nothing interposed between it and the bone but the tendinous insertion of the coraco-brachialis muscle. It happens, however, that the median nerve lies immediately over the artery in this situation, a circumstance which causes compression of the latter to be attended with considerable pain, and productive of injury to the nerve if maintained for too great a length of time.

As the trunk of the brachial artery and several large nerves traverse this part of the arm, it is obvious that wounds in this region are liable to be attended with more serious consequences than those of any other part of the arm. A wound in the posterior region of the arm may be attended with considerable hæmorrhage, if it should happen to penetrate so deep as to divide the profunda artery, or it may cause paralysis of the extensor muscles of the hand and fingers by dividing the radial nerve.

When the humerus is fractured, the consequent derangement of the fragments varies according to the part at which the bone happens to be broken; when fracture occurs immediately above the insertions of the pectoralis major and latissimus dorsi, the lower fragment is brought inward towards the axilla by the action of these muscles, and drawn upwards by the action of the deltoid, biceps, coraco-brachialis, and long head of the triceps, whilst the extremity of the upper fragment is rather turned outwards by the supra-spinatus. In cases where the humerus is fractured immediately above the insertion of the deltoid and below the attachments of the latissimus dorsi and pectoralis major, the deltoid will draw the lower fragment upwards and outwards, whilst the upper fragment will be drawn inwards towards the axilla by the pectoralis major and latissimus dorsi. If the bone be broken immediately below the insertion of the deltoid, little or no displacement of the fragments may ensue, as the opposing forces exercised on the superior fragment by the deltoid on the external side, and the pectoralis major and latissimus dorsi on the internal, pretty nearly counterbalance each other; it more generally happens, however, that the upper fragment is turned outwards by the preponderating action of the deltoid upon it, whilst the lower fragment is drawn upwards by the action of the biceps, coraco-brachialis, and triceps. Fractures of that portion of the humerus which is covered by the brachiæus anticus in front and the triceps behind, are often unattended by any very obvious displacement, in consequence of these muscles being inserted into both fragments; fractures near the elbow are occasionally followed by deformities presenting some of the characters of dislocations of the elbow, of which more notice will be taken in the article Elbow.

General inflammatory enlargement of the arm is rare; it sometimes appears as a concomitant affection with inflammation of the veins of the arm consequent on the operation of phlebotomy, in which case it not unfrequently happens that abscesses form along the course of the sheath of the brachial artery; red streaks along the course of the lymphatics and enlargement of the lymphatic glands are sometimes present in consequence of disease or inflammation affecting the hand or fore-arm.

Amputation of the arm below the insertion of the deltoid may be performed either by the circular incision or the double flap; when the latter method is practised, the flaps should be formed on the external and internal sides, by which the more important vessels and nerves will be included in the internal flap.

When circumstances require the performance of amputation above the insertion of the deltoid, the circular operation should never be practised, for the following reason;—in order to obtain a sufficiency of covering for the bone, the pectoralis major, latissimus dorsi, and teres major would all be detached from their insertions, a consequence of which would be that the contractions of these muscles in opposite directions, by drawing asunder the edges of the wound, would not only render complete apposition difficult in the first instance, but moreover their continued action would have the effect of converting the wound into an ulcer, which it would be extremely difficult if not impossible to heal; therefore, whenever we have to amputate so high up, it is the more judicious mode of proceeding to make a flap including so much of the deltoid muscle as will form a sufficient covering for the stump. The importance of attending to the foregoing circumstances was first pointed out by Louis, the learned secretary to the French Academy of Surgery.*

The arteries which require to be tied after amputation of the arm below the insertion of the deltoid are the brachial and inferior profunda on the internal side; on the external side there are often two branches of the superior profunda requiring a ligature, one of which accompanies the musculo-spiral nerve, and the other runs in the substance of the triceps.

When it becomes necessary to tie the brachial artery on account of a wound or aneurism, the varieties of its relation to the median nerve should be carefully borne in mind; at the upper part of the arm this artery has the median nerve external to it, and the ulnar nerve to its inner side; in the middle of the

* Mémoires de l'Academie de Chirurgie, tom. v.

arm the median nerve crosses the artery in general superficial to it, but sometimes underneath it, while in the lower part of the arm this nerve is invariably on its inner side.

When called upon to expose the brachial artery for the purpose of tying it, the surgeon should recollect that the course of the artery may be readily determined by a line drawn from the coracoid process to a point midway between the condyles of the humerus on the anterior surface of the elbow; hence his incision for the purpose of exposing the brachial artery should be always made along the course of this line and perpendicular to the axis of the os humeri. (See Brachial Artery.)

For Bibliography, see Anatomy (Introduction.)

(John Hart.)

ARM, MUSCLES OF THE.—The muscles which clothe the os humeri are part of the *deltoid*, the *biceps*, *coraco-brachialis*, *brachiæus anticus*, the origin of the *supinator longus* in front, and the *triceps* behind.

The deltoid belongs to the shoulder, and will be described with the other muscles of that part. (See Scapular Region.)

1. *Coraco-brachialis (coraco-humeral).*—The coraco-brachialis arises from the point of the coracoid process, in common with the short head of the biceps, tendinous in front and fleshy behind; it separates from the biceps at its middle third, passes inwards, and is inserted tendinous into the internal surface of the humerus a little above its middle between the triceps and brachiæus anticus.

This muscle has in front of it the deltoid and pectoralis major, which cover and conceal from view its upper part; behind it the tendon of the subscapularis, the tendons of the latissimus dorsi and teres major, the axillary artery, the median and the external cutaneous nerves. The latter nerve perforates the muscle about its middle, and passes through its substance to reach the outer side of the arm; hence the epithet *perforatus* has been applied to this muscle. The coraco-brachialis can carry the arm forwards and inwards; when the humerus is fixed, it can act upon the scapula, and by depressing its coracoid angle, elevate the inferior angle and separate it from the ribs.

2. *Biceps flexor cubiti (scapulo-coraco-radial).*—This is a long muscle swollen in the centre, divided above into two portions called heads, one internal short, the other external long. The internal or short head arises from the coracoid process of the scapula in common with the coraco-brachialis. The long head is attached by a long slender flattened tendon to the upper part of the margin of the glenoid cavity, and is united by a dense cellular tissue to the glenoid ligament. This tendon passes over the head of the humerus, and enters the groove between the two tuberosities in which it is bound down by the fibres of the capsular ligament of the shoulder-joint; a prolongation of the synovial membrane also lines the groove, and forms a synovial sheath for the tendon; the tendon terminates in a fleshy belly which unites with the short head to form the large belly of the biceps; the muscle terminates below in a tendon, which, passing over the brachiæus anticus and the front of the elbow-joint, sinks into a triangular hollow between the pronator teres and supinator longus to be inserted into the back part of the tubercle of the radius; but before it sinks into this triangular space, it sends off from its internal side an aponeurosis (the *semilunar fascia* of the biceps), which is inserted into the internal coudyle, and the fascia which covers the muscle at the inner side of the bend of the elbow.

The biceps is covered by the deltoid, the pectoralis major, the fascia of the arm and integuments in front; behind it lies on the humerus, coraco-brachialis, brachiæus anticus, and the external cutaneous nerve; internal to it lie the coraco-brachialis and brachial artery. It bends the elbow and makes tense the fascia of the fore-arm; it is also a very powerful supinator of the hand by virtue of its insertion into the radius. If the fore-arm be extended and fixed, it will depress the scapula on the humerus.

3. *Brachiæus anticus (B. internus, humerocubital).*—When the biceps has been raised from its situation, we observe the brachiæus anticus deeply situated on the front of the arm; it arises by two fleshy tongues, one on each side of the insertion of the deltoid; from the whole of the anterior surface of the humerus, and the internal intermuscular ligament which separates it from the triceps, its fleshy fibres pass downwards in front of the elbow, and end in a broad tendon which is inserted into a triangular roughness on the anterior surface of the coronoid process of the ulna. This muscle is covered in front by the biceps, supinator longus, the fascia of the arm and integuments, the musculo-cutaneous and median nerves, the brachial artery, and the pronator teres; behind it covers the front of the lower part of the humerus and the elbow-joint. This muscle is the most powerful flexor of the fore-arm upon the arm. As Bichat remarks, flexion of the fore-arm takes place *directly* if the brachiæus combines its action with that of the biceps; if either acts alone, the flexion is in the direction inwards or outwards; inwards when the biceps acts alone, outwards when the brachiæus.

4. *Triceps extensor cubiti (brachiæus posticus, tri-scapulo-humero-olecranien.)*—The triceps muscle of the arm is situated on the posterior surface of the humerus, and, as its name implies, has its origin by three heads. The long head arises by a short, flat, thick tendon from a rough portion of the inferior costa of the scapula, immediately below the glenoid cavity, and passing downwards in front of the insertion of the teres minor, and behind the teres major it forms a large belly, which covers the posterior surface of the os humeri. The second or short head arises from the outer and back part of the os humeri, beginning by a pointed origin immediately below the insertion of the teres minor; it continues to arise from the external ridge of the humerus as low down as the external condyle; from the surface of the bone behind this ridge, and from the back part of the external intermuscular ligament. The third head, which is the shortest, called

brachiæus externus, arises by an acute point from the internal ridge of the os humeri, beginning immediately below the insertion of the teres major; it also arises from the internal ridge as far down as the internal condyle, from the surface of the humerus behind this ridge, and from the posterior surface of the internal intermuscular ligament. The three heads unite above the middle of the os humeri, and cover the whole of the back part of that bone; they form a thick broad tendon, which is inserted into the rough surface on the superior part of the olecranon process of the ulna, adhering closely to the ligamentous fibres covering the posterior surface of the synovial membrane of the elbow-joint; the lowest fibres of the second and third heads of this muscle, which arise from the back of the condyles, run nearly horizontally into the tendon.

The triceps is covered posteriorly by the teres minor, deltoid, fascia of the arm and integuments; in front it is in contact with the posterior surface of the humerus, the intermuscular ligaments, and the back part of the capsule of the elbow-joint. This muscle extends the elbow; when the long head contracts, it draws the scapula towards the humerus, and, if the scapula be fixed, it draws the humerus backwards.

For Bibliography, see Muscle, and Anatomy (Introduction).

(J. Hart.)

ARTERY, (normal anatomy): αρτηρια, απο του τον αερα τηρειν, ab aere servando. Fr. *artere.* Germ. *Pulsader, Schlagader.* Ital. *arteria.* The arteries are the vessels which carry the blood from the heart, and distribute that fluid throughout the body. The trachea was originally called artery from the circumstance of its containing the air which it transmits to the lungs. The term artery was exclusively applied to the trachea by Hippocrates and his cotemporaries, by whom the vessels now called arteries were described as pulsating veins. Aristotle restricted the term artery to the trachea, and described the aorta as the lesser vein. We find these vessels called arteries in the writings of Aretæus, Pliny, and Herophilus, probably on account of the adoption of the opinion of Erasistratus, who taught that they contained a vapour or spirit. The vessels now known as arteries, however, were more distinctly so designated by Galen, who affirmed that they were full of blood, and described the arteries and veins as forming each a tree, whose roots implanted in the lungs, and whose branches distributed through the body, were united by a common trunk in the heart.

There are two great arterial trunks—the aorta, which arises from the left ventricle of the heart, and the pulmonary artery, which arises from the right ventricle of that organ. Each of these vessels has an origin, a trunk, and branches, which divide and subdivide in an arborescent form, until they are reduced in size to the most delicate degree of minuteness, terminating in the capillary vessels, which can be traced entering into all structures except cartilage, hairs, and epidermoid parts. Striking as the contrast is between the size of the primitive arterial trunks and that of the almost invisible capillary vessels, comparatively few divisions intervene between the two extremes of the arterial system, their number hardly exceeding twenty, as Haller ascertained by counting the divisions of the arteries of the mesentery between the place of their origins from the aorta, and their termination in the capillaries of the intestines.*

That the arteries in general are circular tubes is evident from an inspection of their orifices when cut across, even in the dead body. The walls of the larger arteries, when empty, collapse, so as to present, on a transverse section, an aperture more or less elliptical: when distended, however, either by the blood during life, or by injection in the dead body, these also are circular; so that the circular form may be considered as universal in all parts of the animal system except at the origins of the aorta and pulmonary artery, where the circumference of each of these vessels is distended into three sacculated pouches of equal size, called the lesser sinuses; and in the ascending portion of the arch of the aorta, which has a dilatation on its right side, increasing with years, called the greater sinus.

The arteries in general become smaller in their course in proportion to the number of branches arising from them. To this, however, there are exceptions, of which the aorta presents a remarkable example, being of as great a capacity near the origins of the primitive iliac arteries as it is in its thoracic portion, and the vertebral arteries are as large where they enter the foramen magnum of the occipital bone as where they arise from the trunks of the subclavians, notwithstanding that they have given off many branches in the intermediate part of their course.

Wherever an artery runs for some distance without giving off branches, it appears to suffer no perceptible diminution in its size, as has been ascertained by the experiments referred to by Baron Haller,† and repeated by Mr. Hunter,‡ in which the common carotids were found as capacious near the place of their division into the external and internal carotids as at their origins; and the same remark being considered as equally applicable to all other arteries similarly circumstanced, it has been stated in general terms that the arteries and their branches are cylindrical, and that the whole of the arterial system is a series of cylindrical tubes.

Although the cylindrical form is pretty general throughout the arterial system, it is by no means accurately preserved. Several arteries increase in size in the progress of their course; of this we have examples in the umbilical arteries, which expand as they approach the placenta, and the spermatic arteries, especially in the bull and wild boar, which enlarge considerably as they proceed to their destination. Moreover, Haller§ and Martinus have shown

* Haller, Elementa Physiologiæ, t. i. sect. 1. § 17.

† Elementa Physiologiæ, t. i. s. 1, § 3.

‡ Treatise on the Blood, &c., p. 168 et seq. 4to edit. Lond. 1794.

§ Elementa, t. i. s. 3, § 3.

by experiments, that in every instance where an artery divides in the human body, it undergoes a dilatation immediately before such division; and this fact derives confirmation from the experiments of Mr. Hunter on the carotid arteries: it is much more unusual for an artery to diminish in size in its course unless it has furnished branches. Santorini* states, however, that he observed the carotid artery of an ostrich (Struthio camelus) to have become narrower in a portion of its course of six inches in length, for which space no branch had been given off.

The arteries become smaller and more numerous by repeated divisions: the combined area of the branches of each artery, however, exceeds the area of the trunk from which they are given off, in every instance, in consequence of which the capacity of the arterial system, as a whole, is increased in proportion to the number of its divisions. It is from this circumstance that the arteries have been said to represent a cone, the apex of which is at the heart, and the base in the capillaries.

When an artery divides into several branches of unequal size, the largest usually continues its course in the direction of the original trunk.

The branches of the arteries are for the most part given off at acute angles; some few, as the superior aortic intercostals, go off at obtuse angles, and the lumbar arteries arise from the aorta at right angles.

The arteries appear in general to take the shortest course to the parts they supply; hence the tendency they have to run in straight lines.

In many situations the arteries are remarkable for having a tortuous course, as is particularly evident in the arteries of the stomach, intestines, bladder, uterus, lips, iris, &c., where this disposition appears to be a provision to obviate any interruption to the circulation which might result from the great or sudden changes of volume, form, or situation to which those organs are subject in the performance of their functions: in other instances the arteries appear to be contorted for the purpose of breaking the impulse of the systole of the ventricle on the blood, and thereby moderating the force with which that fluid is propelled into vessels partaking of the delicacy of structure of certain organs to which they are distributed, as the arteries of the brain, spleen, testicle, &c.

The smaller arteries, running among loose structures, are rendered tortuous during each systole of the ventricle of the heart, a phenomenon which we have frequently witnessed where such vessels were exposed for a few inches of their course during surgical operations.

Anastomoses.—The several parts of the arterial system communicate freely with each other; and these communications, known by the name of anastomoses,† are more frequent between the arteries in proportion to the remoteness of these vessels from the heart. Three kinds of anastomosis have been distinguished by anatomists: first, two vessels of nearly equal size approach and join so as to form an arch in such a manner as to render it impossible to determine the exact point of their union: this arch gives off smaller vessels. Of this kind is the anastomosis which takes place between the arteries of the intestines and the arteries in the neighbourhood of joints. Secondly, two arteries are sometimes connected by a transverse branch, as the two anterior cerebral in the arterial circle at the base of the brain. We find this kind of communication, also, between the two umbilical arteries as they approach the placenta. Thirdly, two arteries join at an acute angle, so as to form a single trunk: thus the two vertebral arteries form the basilar, the two anterior arteries of the spinal cord unite in a single trunk; and in the fœtus the ductus arteriosus joins the thoracic aorta in a similar manner. Besides these more obvious communications between vessels of a larger size, the anastomoses of the capillaries are so frequent as to give to those vessels, when successfully injected, the appearance of a fine net-work.

It is by means of the anastomoses that the circulation is carried on in a limb after the trunk of its chief artery has been obliterated by disease, injury, or a surgical operation; and the well-known efficiency of the anastomosis of arteries in re-establishing the circulation in parts from which the direct supply of blood through the principal artery has been cut off, has led to the performance of some of the most brilliant operations by which modern surgery has been raised to the exalted rank it holds at the present day.

The larger trunks of arteries are inclosed within the cavities of the body, or run their course on the sides of the limbs least exposed to external injuries, being in general deeply situated in the intervals between the muscles, so as to be protected against wounds or other external injuries, to which they are therefore less exposed than if they had been more superficially situated.

The arteries and their branches are every where surrounded by a layer of cellular tissue, called the arterial sheath, connected more or less intimately with the neighbouring structures, but having so loose an attachment to the arteries as to allow them to glide freely on its inner surface in all their motions, by which means they frequently escape being injured when penetrating wounds traverse parts contiguous to them; and it is owing to the looseness of the attachment of the arteries to their sheath that they retract so remarkably within it when cut across. The sheath is generally strongest around the arteries most exposed to external injury: thus it is particularly strong where it surrounds the arteries of the limbs; it is less distinct on the arteries within the thorax and abdomen, many of which receive coverings from the serous membranes; and it is so extremely delicate around the arteries of the encephalon as to have its existence in this situation questioned by some anatomists.

Structure of arteries.—The arteries are of a pale buff colour when empty. The absolute thickness of their parietes is greatest in the larger trunks, but more considerable in proportion to their calibre in the smaller branches.

* Observationes Anatom. c. 7. n. 6.

† From *ανα, per, στομα, os.*

The parietes of arteries are divisible into three tunics, known by the names of external, middle, and internal.

The *external tunic*, called the *cellular* coat, (*tunica cellulosa propria* of Haller,) is of a whitish colour, thin, dense, and firm: it is formed of condensed cellular tissue, containing fibres closely interwoven and crossing each other at obtuse angles to the length of the vessels. The structure of this tunic is loose on its external surface, and connected by delicate laminæ with the arterial sheath: its internal surface is very closely attached to the external surface of the middle tunic.

The middle tunic of the arteries (the *tunica musculosa* of Haller) is dense, firm, of a reddish yellow colour, and composed of fibres, which, on a superficial view, seem to run transversely: when this tunic is submitted to a closer examination, we find that none of its fibres are sufficiently long to form perfect rings encircling the whole of the circumference of the vessels; they are all short and straight, with a slight degree of obliquity in their direction, and their extremities are lost among the neighbouring fibres. The middle tunic may be divided into several layers by the knife of the anatomist, and these are found to increase in density from the external to the internal surface. There are no longitudinal fibres in this structure.

As Haller has remarked, the middle tunic of the arteries is not continuous with the muscular substance of the heart. For the description of the manner in which the middle tunic of the arteries is connected with the heart, and of the fibrous structure interposed between the muscular texture of that organ and the middle tunic of the arteries, we refer to the article Aorta. The continuity of the middle tunic through all parts of the arterial system is uninterrupted. Although the absolute thickness of this tunic is greatest in the aorta and larger trunks, its thickness in proportion to the area of the vessels manifestly increases as these diminish in size; wherever an artery is curved, it is thicker on the convex than on the concave side, and in all the angles formed by the divisions of arteries its thickness is more considerable than in other situations. The colour of the middle tunic is yellower in the larger trunks and more of a reddish tint in the smaller branches. The middle tunic of the arteries has a degree of firmness sufficient to preserve the circular form of the artery even in its empty state, and after the other tunics have been removed. This tunic possesses a slight degree of strength and elasticity in the longitudinal direction; in the circular direction it exhibits both these properties in a more marked degree. The strength and elasticity of this tunic diminish progressively from the larger to the smaller arteries. There is so close a resemblance between the substance of this tunic and the yellow elastic fibrous tissue of the ligamenta subflava connecting the crura of the vertebræ, as well in its yellow colour and the firmness of its fibres, as in its elastic property, that many anatomists regard both these structures as being nearly if not perfectly identical. Mr. Hunter instituted a variety of experiments to prove that this tunic possessed a power of contraction similar to that of muscular structure in addition to its elasticity; but, notwithstanding the results of the researches of this great anatomist and physiologist, by which he showed, in the clearest manner, that the arteries were endowed with a power of contraction totally distinct from their property of elasticity, he never demonstrated, in a positive and unequivocal manner, the presence of muscular fibres in it, nor has any other anatomist, who, since his time, may have investigated the subject of the structure of this tunic, been more successful in discovering in it any decided trace of muscular fibres. Beclard* considers it to be a peculiar elastic tissue having an intermediate character between muscular and ligamentous fibre.

From carefully examining this structure, it appears to differ both from the yellow elastic fibrous tissue and from the muscular tissue; possessed of the elasticity of the former, but differing from it in being composed of fibres of a softer consistence and more easily torn; from the latter it differs not only in the colour and consistence of its fibres, but moreover in the slow and gradual mode of its contraction under the influence of mechanical or chemical stimuli; unlike the muscular fibre, it retains its power of resistance as perfectly in the dead as in the living body.

Bichat† asserted that there was a total absence of cellular tissue in the structure of the middle tunic of arteries. Meckel, who ranks higher as an authority for matters of fact in anatomy, has admitted this assertion as if it were an established fact: neither of these authors, however, has advanced a single valid argument or brought forward a well-founded proof in support of the correctness of this statement; wherefore we feel the less reluctance in registering our dissent from such high authorities on this point, which we found on the consideration of the following circumstances:—

First, there is no analogous instance of an organized structure receiving bloodvessels and nerves into which cellular tissue does not also enter as a component part.

Secondly, we have the authority of the accurate and learned Haller, in testimony of the fact of the fibres of the middle tunic of the arteries having cellular tissue interposed between them, being, as he expresses himself, "cellulositate paucissimâ separatæ." Beclard entertains a similar opinion founded on the circumstance that when a portion of an artery is stripped of its external tunic, granulations will shoot up from the exposed surface of the middle tunic.

Thirdly, we have frequently observed that, when a portion of an artery stripped of its external tunic, is divided longitudinally and macerated in water for several days, the middle tunic increases in thickness, and its fibres become more distinct and are more easily separated from each other; by continuing the

* Anatomie Générale, p. 325.

† Anatomie Générale, tom. iii.

maceration, the intervals between the fibres become greater, and as the putrefactive process sets in and advances, the whole substance of the middle tunic takes on the form of a spongy mass, and ultimately the fibres cease to be any longer discernible, having been reduced to the state of a soft pulp, while the cellular structure is rendered more evident. The following appears to us to be the rationale of the phenomena above described: the increase in thickness which the middle tunic at first undergoes is owing to the cellular tissue interposed between the fibres imbibing the water in which it has been immersed, in virtue of its hygrometric property; and the spongy appearance observable after the maceration has been continued for a length of time, is the result of the cellular tissue having the property of resisting decomposition by putrefaction much longer than the fibrous tissue.

The internal tunic (*intima* of Haller) is the thinnest of the three; it is continuous with the lining membrane of the heart, in extending from which into the arteries it forms a duplicature, contributing to the composition of the semilunar valves: in the larger arteries, when empty, it sometimes forms longitudinal folds; in some arteries, such as the poplitæal, and the brachial at the bend of the elbow, it presents transverse folds or wrinkles; it also forms transverse wrinkles in arteries which have retracted after amputation: its internal surface, which is in contact with the blood in the living body, is smooth, polished, and bedewed with a fine exhalation; its external surface adheres to the internal surface of the middle tunics in the larger trunks of the arteries; this tunic may be divided into two layers, the internal of which is thin and transparent, while the external is whitish and opaque, having its structure blended with that of the middle tunic; it is the *tunica cellulosa interior* of Haller, and is the seat of the calcareous, steatomatous, and atheromatous deposits, which so frequently occur as morbid appearances in the coats of the arteries. We do not perceive fibres nor any other signs of organization in the inner layer of this tunic in its healthy state; it is almost completely inelastic and very brittle; it tears with equal facility in every direction; compared with other structures it bears the closest resemblance to the arachnoid membrane of the brain; the smooth and highly polished condition of the free surface of this tunic is an admirable provision, whereby the effect of friction in diminishing the velocity of the passage of the blood through the arteries is reduced to the smallest possible amount.

The following mechanical contrivance observable in the interior of the arteries would appear to be a provision for facilitating the distribution of the blood through the divisions of the arterial system. As the branches of the arteries mostly arise from the trunks at acute angles, the portion of the circumference of their orifices on the side next the heart is smooth and depressed, forming a sort of channel sloping gently from the trunk into the branch, while the opposite side, or that more remote from the heart, is bordered by a ridge of a semilunar valve-like form, composed of a duplicature of the lining membrane in which there is included a portion of the middle tunic; the more acute the angle at which the branch arises, the greater is the prominence of this ridge; it is altogether absent where branches arise at right angles, as in the case of the emulgent arteries, and where branches arise at obtuse angles to the trunk, it is found at their orifices on the side next the heart.

The aorta and pulmonary artery are each provided with three valves at their origins from the ventricles; these valves, called sigmoid or semilunar from their semicircular form, are attached by their inferior borders, which are convex, to the margins of the semicircular flaps or festoons, into which the edge of the commencement of the middle tunic of the artery is divided; the superior edges of each of these valves, which are free and floating, form two concave lines, separated by a projection in the centre, in which is contained a small cartilaginous body, called tubercle, *globulus Arantii* or *corpus sesamoideum*. The portions of the walls of the artery corresponding to the valves are dilated in the form of pouches, more marked in the aorta than in the pulmonary artery; these are the sinuses of Valsalva. The semilunar valves are composed of a duplicature of the lining membrane of the artery, including within it a thin but strong fibrous expansion, continuous with the fibrous structure, which connects the middle tunic of the artery with the tendinous ring encircling the arterial opening of the ventricle; the free border of each valve contains a small fibrous cord, as described by Beclard, having the globulus Arantii attached to it in its centre.

An increase or diminution in the number of the sigmoid valves is of rare occurrence, more frequently presented in the pulmonary artery than in the aorta, and oftener consists in the number of valves being increased to four than diminished to two.*

The mechanism of these valves is such as to prevent the blood flowing in a direction contrary to its regular course; for when that fluid is propelled towards the ventricle, they are separated from the parietes of the artery, and being distended by the column of blood pressing against their superior surfaces, they are laid across the area of the vessel, which they completely fill up by their edges being thus brought into perfect contact and the globuli Arantii meeting in the centre. There are no valves in the arteries in any other situation.

The arteries, like other organized structures, are furnished with proper nutritious arteries and veins called *vasa vasorum*. The aorta and pulmonary artery at their commencement receive some branches from the coronary vessels of the heart; in all other situations the vasa vasorum are supplied by the neighbouring bloodvessels; the vasa vasorum are very evident in the external tunic of the arteries, they can be traced until they penetrate the substance of the middle tunic, but not farther;

* Meckel, Handbuch der menschlichen Anatomie. Band. i.

they are more numerous and larger in young than in adult and old subjects.

Absorbents are not visible on the coats of any arteries except the larger trunks; however, the removal of coagula formed in the interior of all arteries after the application of ligatures may be regarded as proving the existence of absorbents in every part of the arterial system.

The arteries are plentifully supplied with nerves, of which the aortic system receives more in proportion than the pulmonary artery, and the smaller arteries more than the larger trunks. The trunk of the aorta, the pulmonary artery, and the arteries of the head, neck, thorax, abdomen, and those of the genital organs, receive their supply from the nerves of organic life. These form a very intricate plexus on their surface. The arteries of the extremities receive their supply of nerves from those of animal life in their neighbourhood. Two sets of nerves have been described as being furnished to the arteries; one set, consisting of softer nerves, of a flattened form, are said to be lost in the cellular or external tunic, *nervi molles;* the other set, more firm and round, penetrate the middle tunic, in which they form a thin membraniform expansion, containing distinct fibres. Meckel* justly considers the internal nerves as subdivisions of the larger flattened external branches. No nerves have yet been discovered on the umbilical arteries, and the arteries of the brain are supposed to be without any. The nerves of the arteries become less apparent in old age.

The specific gravity of the arteries exceeds that of distilled water in the proportion of 106 to 100. They are proportionally lighter and less dense than the veins; while the veins possess more power of resistance, and are not so easily ruptured as the arteries.

Physical properties.—Of the physical properties of the arteries the most remarkable are the firmness of their parietes, their power of resistance, and their elasticity. It is owing to the firmness, which principally resides in their middle tunic, that they preserve their circular form in the empty state.

Their power of resistance has been made the subject of experiment by Wintringham,† and, more recently, by Beclard,‡ from which the following results have been obtained.

Their power of resisting rupture is very great, and is generally in proportion to their thickness, being greater in the aorta than in the pulmonary artery. As the arteries diminish in size, their absolute resistance diminishes; however, as their relative thickness and softness increase, their extensibility and relative resistance undergo a proportionate augmentation. The resistance of all arteries of equal volume is not the same: for instance, that of the iliac artery is greater than that of the carotid. It is in the external tunic that the power of resistance in the longitudinal direction resides; the resistance in the circular direction is much greater, and is owing to the middle and external tunics conjointly; the internal tunic has very little power of resistance in either direction. The middle and internal tunics are as remarkable for their fragility as the external is for its toughness and great power of resistance; hence it is, that when a ligature is tightened on an artery, the two former are divided, while the latter remains unbroken, as proved by the experiments of Dr. Jones.*

The successful employment of torsion of the arteries as a means of suppressing hæmorrhage is in like manner owing to the greater power of resistance possessed by the external tunic as compared with the other two. The process by which arteries are obliterated by torsion is thus explained by M. Amussat,† to whom belongs the merit of having been the first to propose and practise it. The divided extremity of an artery is seized between the blades of a forceps, and drawn out beyond the surface of the wound: the vessel is then taken hold of with a second pair of forceps a few lines higher, and held firmly while the operator commences to twist the forceps with which he holds the extremity of the vessel in the direction of its axis, making from five to nine or ten turns, according to the size of the vessel operated upon. On examining an artery which has undergone this process, it will be found that the middle and internal tunics of the twisted portion have been broken in several places by the external tunic, which, remaining unbroken, is formed by the twisting process into a sort of spiral ligature, so tightly applied round the inner tunics as to set at defiance every attempt to unravel it by twisting the vessel in the opposite direction.

The arteries are highly elastic; they admit of considerable distension in the longitudinal direction, and quickly contract to their original length on the cessation of the distending force. In the transverse direction they yield less, and after distension resume their previous state with greater force. When a fluid is injected with some force into the arteries in the dead body, they become distended and elongated; and if, when they are in this state, the force with which the injection was propelled be removed, they will contract to their previous state, or nearly so, expelling a portion of the fluid which had been thrown into them. During life the arteries are in a state of elastic tension, so that, when divided, their cut extremities retract within their sheath.

The arteries are endowed with the power of contracting in a gradual manner, which they exhibit under the following circumstances:—when the passage of the blood is stopped in the principal artery of a limb, the vessel gradually contracts, its cavity is reduced in size, and ultimately becomes obliterated by degenerating into a filamentous band of cellular tissue; while the collateral branches, taking up its function of conveying blood to the distant parts, are proportionally enlarged, rendered more tortuous, and increased in length. In process of time the number of enlarged collateral branches diminishes, and one or more vessels of increased size become as it were promoted to

* Op. cit.

† Experimental Inquiry on some parts of the Animal Structure. Lond. 1740.

‡ Anatomie Générale, p. 373.

* Treatise on Hæmorrhage. Lond. 1805.

† Archives Générales de Médecine, t. xx. Août, 1829, p. 606.

the station which the principal trunk had held in the circulation while in its normal condition. Several distinguished anatomists and physiologists have considered the property of elasticity of the arteries sufficient to account for all the phenomena of the circulation of the blood through these vessels. This opinion has been principally insisted on by Haller, Bichat, Nysten, and, at the present day, by Magendie; elasticity, however, can only account for contractions taking place in consequence of previous distension, and is equally evident after death as during life: but observation and experiments have shewn that, in the living body, the arteries possess an additional power of contraction, by which their calibre may be diminished in various degrees; in some instances even almost to obliteration. And this power of contraction has been considered by many anatomists to indicate the existence of a property of irritability in the arteries, similar to, if not identical with muscularity. The existence of irritability in the arteries was denied by Haller in consequence of his not having succeeded in rendering it evident by the application of chemical or mechanical stimuli. Bichat, Nysten, and Magendie, embraced a similar opinion, on the strength of the following facts:—mechanical or chemical stimuli, even the galvanic fluid, applied to the surfaces of the arteries, produce no motions; when the fibres of the middle tunic are dissected off in successive layers in living animals, they are not observed to display that quivering motion visible among the fibres of muscles similarly treated. When cut longitudinally, the inner surface of the arteries does not become everted like that of canals, such as the intestines, which have a decidedly muscular tunic: they do not contract when separated from the heart. The finger introduced into a living artery is not constricted; stimuli applied to the nerves of particular arteries, or to the nervous system generally, do not produce contractions; strong acids applied to arteries produce a corrugation or crisping of their structure, not a contraction, like that of muscular structure.

The contrary opinion as to the existence of irritability in the arteries has been maintained by some of the most distinguished and accurate anatomists and physiologists, among whom are Hunter, Sœmmerring, and Verschuir. It may be stated in a general manner, as an objection to the arguments of Bichat, founded on the circumstance of the arteries not having contracted when stimuli were applied to them in some experiments which he performed, that other irritable parts, even the muscles themselves, do not at all times contract on the application of stimuli. In fact, most of the experiments detailed by Bichat, as proving the absence of irritability in arteries, have been performed by Hunter, Verschuir, and Hastings, and with results directly contrary to those obtained by that very distinguished anatomist. Verschuir* found that the arteries contracted when stimulated by the mineral acids, by electricity, and the application of the point of a scalpel. Dr. Thomson* also saw them contract on the application of ammonia, and when punctured with the point of a fine needle in the living body. Irritating the nerves by the galvanic fluid or by caustic alkalies has been followed by contraction of the arteries.† Mr. Hunter‡ found that the exposure of arteries to the air was followed by their contraction to such an extent as to produce their obliteration. An instance of this we have twice witnessed in the brachial artery when exposed during the progress of an operation for traumatic aneurism at the bend of the elbow. The contraction of divided arteries is well known to be an efficient means of arresting hæmorrhage, in opposition to the force with which the blood is propelled through them by the heart's action.

In conclusion, we may observe that the arteries are proved to be both elastic and irritable; that elasticity predominates in the large trunks, and irritability in the smaller branches; that their irritability, like that of muscles, is under the influence of the nervous system, and obeys the immediate application of chemical and mechanical stimuli, the effects of which must, however, be very much modified by the influence of the elasticity with which they are endowed. (See CIRCULATION.)

In men the arteries are said to have their tunics thicker, and to possess greater density and a higher specific gravity than in women. The arteries are larger, more numerous, and their coats are softer in young persons: they become more fragile, and their elasticity diminishes, in advanced life.

In the progressive development of parts the arteries appear before the heart; but in the chick, during its evolution, the veins of the yolk precede them in their development, as ascertained by the researches of Malpighi,§ Haller,‖ Wolff,¶ Pander,** and Rolando.††

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(*J. Hart.*)

ARTERY, PATHOLOGICAL CONDITIONS OF.—Notwithstanding the brilliant success that has attended the labours of British surgeons in the department of their profession having reference to the arteries, a success that has deprived hæmorrhage of its terrors, and aneurism of half its danger, the pathology of the arterial system is still far from being perfectly understood. Doubtless, the appearances of disease in its more advanced and destructive forms have been accurately described as they have been carefully observed, but that invaluable information which enables a practitioner to detect its early and silent approach, to trace its progress by connecting each symptom with the morbid change that is going forward, and to predict with accuracy the time and the manner of its termination, is as yet but very imperfect. Many circumstances have unavoidably contributed to this. It is quite possible that arteries may be in an unhealthy condition without presenting any indication of disease during life, which is, therefore, in the subsequent examination overlooked. It is more than questionable whether arteritis occasions pain, for it has been observed in situations in which the patient never complained, and as persons do not die from inflammation of the arteries, the intensity of the disease has time to subside, and its effects only remain for observation in alterations in the coats of the vessels, or in an aneurism. Many able and intelligent practitioners who have met with aneurisms without number, have yet not seen an example of acute arteritis, and are disposed to consider the red colour of the internal membrane of the vessel observed in cases presumed to be so by others as a staining by the blood after death. These facts prove the imperfection of our knowledge of the pathology of the arterial system; and years of patient investigation must still be passed both by the bed-side and in the dissecting-room before the dreams of hypothesis give place to the certainty of scientific demonstration.

In prosecuting this inquiry, that source of information so valuable in the elucidation of other subjects in physiology, the experimenting on animals, is wholly closed; the artery of the animal bearing no analogy whatever to that of man, either in susceptibility of disease or in the powers of reparation after injury. It appears, from Dr. Jones's* experiments, that the artery of a dog, if wounded only to a moderate extent, is capable of re-uniting and of healing so completely that after a certain time the cicatrization cannot be discovered, either on its internal or external surface; whilst it is nearly certain that in man the wound of an artery can only be healed by the complete obliteration of the vessel at the spot where it has been injured. It is difficult if not impossible to bleed an animal to death by opening a moderately sized artery, whilst few surgeons would be willing to entrust a wound of a branch of the temporal in man to the resources of nature alone. The facts, too, that aneurism is a disease unknown among inferior animals,—that it cannot, by any ingenuity of contrivance, be artificially produced, and that the earthy depositions so commonly met with in the arteries of aged persons are peculiar to the human species, would tend to shew that some difference of structure existed, some peculiarity favourable to the production of dis-

* Jones on Hæmorrhage, pp. 107 to 111 incl.

ease in the artery of the latter. Indeed, in examining and comparing the artery of a sheep or a dog with that of man, some very obvious differences are apparent: the former is firmer if not actually thicker in its coats; it maintains its circular form more completely, and seems to possess the quality of elasticity in a greater degree of perfection. These circumstances, however, are insufficient to account for that comparative freedom from disease; and probably the greater susceptibility of man may be traced to the indulgence of certain habits and propensities from which the animal is debarred, and which, in many other instances as well as in this, seem to be the predisposing causes of disease in the human race.

The surgical pathology of the arteries presents itself in two different though equally interesting points of view, one having reference to the effects of a wound or other injury to a healthy vessel, embracing a consideration of the process by which such injury is remedied or repaired by the efforts of nature alone or by the assistance of art, and the circumstances that influence its success or failure; the other referring to the appearances and consequences of disease, either as it commences idiopathically within the vessel itself, or is propagated from adjacent parts or structures to it. A lesion of the structure of an artery is of but slight importance provided its function is unimpaired, that is, as long as the blood it was destined to circulate passes through it or is conveyed by some other channel in the natural course of the circulation: even the aorta has been obliterated without any serious inconvenience to the individual in whom it occurred. But when the lesion is of such a nature as to interfere with this function, when the blood is allowed to escape either externally as from an open wound, or internally as in the different species of aneurism, results of a most formidable nature ensue, greatly modified, however, in their character and consequences by a number of circumstances highly deserving of attention.

Wounds and injuries of arteries. — It cannot have escaped observation that the nature of the wound or rather of the substance that occasioned it exerts a striking influence on the phenomena both of hæmorrhage and of the process by which it is restrained. Lacerated wounds seldom bleed, although the torn artery may be left hanging out an inch or more beyond the adjacent surface. Gun-shot wounds, also, if the artery is completely divided, are not often followed by hæmorrhage, although some instances to the contrary occasionally happen; but if the vessel is only notched or partially cut, the bleeding is as profuse as from any other cause. If an artery is wounded by a cutting instrument or by puncture, however, the blood is poured out most freely; yet even here there are varieties, according to the size and importance of the vessel, the extent and direction of the accompanying wound, and the circumstance of the division of the artery being partial or complete. In like manner the subsequent progress of the case will exhibit considerable variety, and demonstrate the fallacious views of those who, grounding their opinions on experiment, would limit the process of recovery to one operation, and regard the efforts of nature as alike in all, whereas, as has been remarked by Mr. Guthrie, this process essentially depends on the size and variation of structure of the artery; it is not the same in large as in small arteries; and it is not even quite the same in the upper and lower ends of the same artery.

When a limb has been torn off by a cannon-shot, by the fall of a tree on it, or by any similar violence, the arteries do not bleed: very frequently the main trunk is seen hanging an inch or more from the wound, pulsating, or at least receiving an impulse from the sound portion of the vessel, though (as far as I have observed) not containing blood within it. It hangs white, bloodless, and flaccid in the wound, not very unlike a piece of narrow wetted tape, and is smaller at its extremity than at any other part. This narrow point, which, according to Mr. Guthrie, is formed by the contraction of the artery, is also in his opinion the only barrier to the escape of the blood; for in a case of this description he cut off the end of the artery at less than an eighth of an inch from the extremity, when it bled with the usual vigour. The extraordinary opportunities this gentleman has enjoyed, and the accuracy of observation which his writings evince, entitle his opinions to be received with great deference, although in a physiological point of view it is difficult to conceive how an artery subjected to such a lacerating force should not have its vital properties so much impaired as to prevent its contracting at all, more particularly at the spot where it was torn across, and where, therefore, the greatest injury was sustained. At the same time there is no other mode of explaining the case. All that portion of the artery that is pendulous from the wound appears to be smaller in diameter than in its healthy state; there is cellular tissue at its torn extremity, but it is not injected with blood, and the coagulum, if any, within the vessel, is so small as to be incapable by its mechanical resistance of preventing the escape of the blood. As there are scarcely any two accidents attended by exactly the same degree of injury, it is probable that nature in such cases possesses different resources. In one case where the leg had been torn off by the falling of a tree, and left attached merely by a portion of the skin over the gastrocnemius muscle, the posterior tibial artery hung nearly three inches from the wound. As the man had been carried a distance of eleven miles, and seemed much exhausted, it was not deemed right to attempt more at the moment than merely to relieve him of the annoyance of the pendulous portion of the limb by cutting through the skin. This was performed incautiously, for no inconvenience was apprehended; about an inch of the extremity of the artery was removed, and it bled just as in Mr. Guthrie's case. In another instance where the arm was shattered by a steam-engine with such violence that some of the muscles torn from their attachments remained upon the wheel, the artery, divided in the subsequent amputation more than two inches above the wound, did not pour out one drop of blood. In others, still, the cellular sheath of the artery has been seen injected with blood in a state of coagulation, the pressure of which on its orifice seemed to be sufficient to prevent bleeding.

We are told that the observation made by Amussat,* that in gun-shot wounds where all the parts were lacerated, the extremities of even the larger vessels did not bleed, suggested to him the application of the phenomenon to practical surgery, and led to the practice of the *torsion* of arteries. This operation consists in laying bare a portion of the divided artery, and carefully detaching it from the surrounding cellular membrane until its own cellular tunic is distinctly to be seen; it is then seized with a forceps, not unlike the common artery-forceps of Bell, and twisted on its axis until the extremity engaged between the blades is completely detached by the torsion. This forms something like a knot or knuckle at the end of the vessel, which mechanically blocks it up; a coagulum is formed within, and the remainder of the process is said nearly to resemble that which succeeds the application of a ligature. Not having practised torsion on a vessel of any considerable size in the human subject, nor had an opportunity of examining after death a case thus treated, I am unable to comprehend, with sufficient precision, the exact process that is established. In experimenting on the femoral arteries of dogs, I have always found that the immediate obstacle to the flow of blood was a coagulum situated at the orifice, and apparently entangled in the lacerated cellular coat; but for the reasons already mentioned, little confidence can be placed in such investigations.

Hitherto we have been considering those wounds of arteries, which, however important in other respects, are not attended by hæmorrhage, and although ignorant of the operations of nature in effecting this result, it is of the less consequence, inasmuch as it is not likely we shall attempt to imitate them, or entrust a large-sized vessel to torsion alone. The wounds of arteries, accompanied by loss of blood, present themselves under very different circumstances; there is always anxiety, agitation, and dismay on the part of the sufferer, and it may be that promptness and decision in the practitioner shall be required to preserve life. In any of these awful situations, coolness and self-possession can alone ensure a freedom from embarrassment, and these qualities cannot be expected in any individual who has neglected to make himself acquainted with the nature of the mischief that has occurred, and the means by which it may be remedied.

The phenomena attendant on arterial hæmorrhage occasioned by incised and punctured wounds exhibit remarkable varieties, according to the size, and of course to the structure of the vessel; to the circumstance of its having been fairly divided, or only notched, or punctured; to the wound being so large and patulous as freely to permit the escape of all the blood externally, or so small or oblique that the fluid, though withdrawn from the circulation, is still retained within the limb. There is still another condition of wounded artery in which the blood that escapes from it is poured into an adjacent vein, and continues to circulate, though not in its proper vessel. However, these latter cases are usually considered and described as forms of aneurism, and will, therefore, not be noticed until there is an opportunity of comparing the different species of that disease one with another.

When a large artery is divided in an open wound, it may happen that the patient dies almost instantaneously, not from the absolute quantity of blood lost, but from its being withdrawn too suddenly from the circulation, just as syncope is often produced by the rapid abstraction of blood in the common operation of phlebotomy. However, this is not uniformly the case, and experience has proved that vessels of such size and importance as the carotid and femoral arteries may be divided, and yet sufficient time allowed for the successful interposition of art. Mr. Guthrie states, that when the femoral artery is cut across in the upper part of the thigh, the patient does not always bleed to death, although frequently lost; while if the division takes place in the middle or lower half of the thigh, the bleeding will probably cease of itself. When, however, an artery of still smaller size is divided, the powers of nature are almost always competent to restrain the hæmorrhage, and consequently it is from an examination of vessels of this class under such circumstances that a knowledge can be obtained of the nature and extent of these powers.

When a vessel of moderate size is divided, the blood is poured forth in jerks from its open mouth in a large and full stream; soon, however, this stream is seen to become diminished in size, and most probably it ceases to flow per saltum. If the patient faints, the bleeding perhaps ceases altogether, nor will it be renewed unless accident or indiscretion gives to the blood an impetus sufficient to overcome the obstacle that opposes its exit, whatever that may be. When the artery is divided, its middle coat retracts immediately that its natural state of tension is removed, withdrawing with it the lining membrane, but leaving the cellular, to which it is but loosely attached, hanging out beyond it. It contracts, too, in diameter, as is evidenced by the diminished stream of blood. The power by which this contraction and retraction are performed is a vital property inherent in the artery itself; it has been called muscularity, and endless arguments have thus been raised about a name, as if no tissue in the body but muscle could be capable of contraction. But it operates in a manner very different from the rapid and decided contraction of muscle; it is slow, gradual, and continued, and, therefore, is longer in bringing the large vessel into a state favourable for the suppression of hæmor-

* Dictionaire de Chirurgie de Rust, tom. ii.

rhage than the small one. The next step is the entanglement of blood in the cellular coat of the vessel and its consequent coagulation when it comes to press in the most advantageous direction on its open mouth, and the hæmorrhage is stopped.

Thus the *immediate* agent of nature, in the suppression of hæmorrhage, is pressure effected by the clot of blood, whilst the vessel is placed by its own properties in the condition most favorable to the operation; and it is curious to observe how universally the principle has been acted on, though probably first suggested by accident or empiricism. The burning iron of the older surgeons produced the pressure of an eschar; agaric and sponge entangled the blood and retained a coagulum on the spot; even the more modern invention of the ligature is in the first instance only pressure, but with the manifest advantages of being applied directly and immediately, of being firm and not likely to slip, and independent of rest, position, and bandage, which are indispensable when other modes of compression are had recourse to.

But the *permanent* suppression of arterial hæmorrhage can only be effected by the actual obliteration of the vessel at the spot where it had been opened or divided, a process that is the result of inflammation of the lining membrane, and of the coagulating lymph thereby poured out, or of the artery ceasing to transmit blood through it, and thus becoming as it were useless in the economy. Both these influences are exemplified in the permanent cure of a wounded artery, for in an incredibly short space of time after the external coagulum has been formed, lymph is effused from the wound in the vessel: and internally, between this lymph and the nearest collateral branch, another coagulum of blood is formed, to which a considerable degree of importance has been attached, though probably without sufficient reason. It cannot be very instrumental in controlling hæmorrhage, because it does not occupy the entire capacity of the artery: its shape is conical, the base lying on the lymph poured out from the wound, from which it gradually tapers to the next branch, and it seems to be formed of a small quantity of the blood, which, being pushed into that branch, remains there, is placed out of the current of the circulation, and must coagulate. The transmission of blood to the limb below is now to be effected through the medium of the anastomosing vessels, which for this purpose become proportionably enlarged. This quality possessed by arteries of increasing their own diameters, or in other words of accommodating themselves to their contents, is curious and interesting, and although not admitting of explanation, cannot for a moment be doubted. No fact has been more satisfactorily proved by dissection, and like the contractility of the artery already noticed, the effects of this power exhibit themselves gradually and slowly. The circulation of the limb seems scarcely to be interrupted, for in a few minutes the arteries below appear, as has been observed by Dupuytren, like soft cords under the finger, evidently filled with blood, but totally devoid of pulsation. It is a long time before this latter proof of a restored activity in the circulation comes to be perceptible, and perhaps is never again equal to what it had been before the occurrence of the accident. The external wound, of course, heals like any other of a similar nature, and it is rare that the limb experiences any inconvenience subsequently. The internal coagulum is soon absorbed, and in process of time the vessel, from the point of division to the next branch above and below, degenerates into an impervious ligamentous cord.

Such is the progress of events when the efforts of Nature are sufficient to arrest the bleeding; but after all it is a fortunate case that ends thus, and experience teaches that there is little wisdom in leaving a moderately sized artery to her resources alone. What more frequently happens is this: the artery retracts and contracts it is true, and a coagulum forms, which, as the patient becomes faint or weak, is allowed to become consolidated, and for that time is sufficient to save him. But he recovers, or perhaps he uses some stimulus or some excitement, and the renewed circulation gradually loosens the clot, and a fresh gush of blood takes place. This recurs frequently, and an hæmorrhagic disposition is formed; the patient becomes pale and exsanguineous, anxious, and in coutinual agitation, and without the intervention of art has but a slender chance of surviving. In these cases, art adopts the principle of the natural cure, only regulating its force, and ensuring its continued operation for the requisite period. The first object to be attained is the application of a sufficient degree of pressure to control the bleeding: the second to maintain that pressure for a length of time to ensure the obliteration of the vessel. This is not the place to discuss the various methods that have been adopted for the accomplishment of these ends; suffice it that the superiority of the ligature has been so far proved by experience, that few surgeons of the present day would feel satisfied in entrusting a large or important vessel to a less powerful or enduring compression. But the ligature is in itself not unfrequently a cause of great and frightful mischief, and, therefore, it will be necessary to examine into all the circumstances connected with this part of the subject.

In practice, a ligature is applied around an artery under two different circumstances; one, in the case of the wounded and bleeding artery, it is placed on the open orifice of the vessel; the other, in the treatment of aneurism, the artery is taken up and tied at a part where it is supposed to be sound and uninjured. When, in either of these cases, an artery is tied, the first effect is obviously to bring its opposite sides into apposition, and to arrest the flow of blood through it. At the same time that the internal and fibrous coats being shorter and less tough yield under its pressure and are divided completely, leaving the cellular coat entire, still sustaining the ligature in its place. The consequences of this division of the internal coats are very similar to those already explained as following the complete section of the artery;

there is the same effusion of lymph, the formation of internal coagulum of the same conical shape and to the same extent, the diversion of the circulation through the collateral branches, and if the case proceeds favorably, the ultimate obliteration of the tube between the place occupied by the ligature and the next anastomosing branch. But the ligature is still to be attended to. The portion of the cellular coat included within its noose sloughs and dies, and is to be detached from the remainder by the absorption of the adjacent sound part. This process takes place at different periods of time according to the size of the vessel; it separates from the subclavian about the twenty-second day after the operation, from the femoral about the sixteenth, and from the brachial so early as the twelfth or fourteenth. Unfortunately matters do not always proceed thus favorably, and the separation of the ligature is the commencement of a series of evils to the patient and of embarrassment to the surgeon, that can scarcely be paralleled in the practice of surgery. It has been found, however, by experience, that a ligature placed on an artery that has been fairly divided, is more rarely followed by those ill consequences that frequently ensue when its continuous tube is tied, and as this latter operation is so intimately connected with the subject of aneurism, and as it will be necessary to become acquainted with the phenomena of inflammation in these structures, in order to understand those of secondary or consecutive hæmorrhage, this part of the subject cannot at present be so favorably discussed.

Morbid states of arteries. Aneurism.—Aneurism (ανευρισμος, vel ανευρυσμος,) is a term of such extensive application as to preclude the possibility of an accurate definition. It has been employed by Corvisart and others to designate certain affections of the heart, but is now most generally used to express a disease produced by a dilatation of an artery, or by solution of continuity in one or all of its coats. It is also applied to any distended condition of a part of the vascular system, such as occurs when an unnatural communication is formed between an artery and vein, constituting the diseases of aneurismal varix and varicose aneurism. The name of aneurism by anastomosis has also been given to those bloody tumours, which, at first appearing only as marks or stains occasioned by a congeries of vessels, increase either with the growth of the individual, or according as the vascular system may be accidentally excited, until finally they produce results of a most formidable description.

Aneurisms have been classed, first, as to the condition of the coats of the artery, a dilatation of them being considered as the *true* aneurism, whilst a rupture or ulceration of them constitutes the *false*: and, secondly, as to the condition of the effused blood, which, if it is contained within a sac or bag, constitutes the *circumscribed* form of the disease, or if it has been poured out throughout the circumjacent cellular tissue, forms the *diffused* aneurism. The nature of aneurism, however, will be better understood by considering it to consist of such a lesion of an artery as will permit the passage of a portion of the blood out of the usual course of the circulation, though not out of the vicinity of the injured or diseased vessel, and according to the different circumstances under which this can occur, the disease will be found to arrange itself under the following distinct species. In the first four of these the effused blood is either partially or entirely withdrawn from the circulation, and becomes coagulated in its new situation: in the others it passes from the usual course of the circulation, but is not withdrawn entirely from it, and consequently does not coagulate.

1. Where by rupture or ulceration of the internal and middle coats of the vessel, the blood is propelled against the external cellular coat, which becomes thus distended into a pouch containing within it the extravasated blood, in a more or less perfect state of coagulation, which pouch is termed the aneurismal sac. This is *circumscribed false aneurism*.

2. The *true aneurism* is when all the coats of an artery, in one particular part of its circumference, are so far deprived of their elastic properties as to yield, become distended, and form a pouch, in which the contained blood is similarly circumstanced.

3. It is not difficult to conceive that the sac of a true aneurism, as just described, will not long endure its state of unnatural distension before its internal and fibrous coats either ulcerate or rupture, and then an aneurismal sac is formed, consisting in one part of all the coats of the dilated vessel, and in the other of the cellular tunic alone. This is obviously a mixed form of aneurism.

4. When there is a wound, rupture, or ulceration of all the coats of an artery, in such wise as to permit the escape of the blood into the adjacent cellular tissue, a *diffused aneurism* is formed. This, for reasons that need not explanation, will be most frequently observed to succeed to wounds or punctures of vessels, but it may also be the consequence of an accidental rupture of the sac of a circumscribed aneurism allowing the blood to pass through it, and spread itself (as it generally does) in every direction throughout the loose cellular tissue of the entire limb.

5. A direct and immediate communication may be established between an artery and a vein lying close upon it, as by the passage of a lancet transfixing one vessel and entering the other. This is the aneurismal varix, obviously occurring with greater frequency as the result of a wound, but nevertheless occasionally seen as the product of disease.

6. A small circumscribed aneurismal sac has been found situated between an artery and vein so transfixed, communicating with both, and permitting a transmission of blood from one vessel into the other. This variety has been named the *varicose aneurism*.

7. A portion of blood may be contained within a new and diseased formation of cellular structure, the precise nature of which is not understood. The trunks of the arteries in

the neighbourhood are neither distended nor ruptured, and the blood within it passes through the general circulation, and of course does not coagulate. It is difficult to class this disease with aneurism in any form, yet is it termed *the aneurism by anastomosis.*

No part of the natural history of any disease can be more interesting than that which has reference to its causes, whether predisposing and remote, or immediately exciting. Certainly, when an aneurism has been formed, a knowledge of the circumstances that occasioned it will not be very useful in contributing to its removal, although it may often assist in forming a prognosis as to the result of an operation: yet if it can be made available in the prevention of the disease, it must prove of no inconsiderable value. It is admitted that aneurism frequently appears suddenly as the result of a blow, a strain, or some violent exertion, the patient being conscious of something having torn or given way within him. With still greater frequency it occurs without any such consciousness on the part of the sufferer, and persons have borne this formidable disease about them for months, and even for years, not only without being themselves aware of its existence, but, if situated internally, without its being recognized by their professional attendants;* and it often happens that a patient complains of the crookening of the fingers or the numbness of the foot, unmindful of the tumour under the clavicle or in the popliteal space. Without denying that an artery, in a perfectly healthy condition, can become the seat of aneurism, because there are too many facts apparently in support of such an opinion, it may be remarked that if such was generally or even frequently the case, the disease ought to be much more common amongst the labouring poor, and also that it should prevail amongst some particular trades. These considerations lead to a belief, that previous to the occurrence of spontaneous aneurism, the artery has undergone some change predisposing to it, although it may not be so easy to point out the nature of that change, or the causes that lead to its production.

It is observed that aneurism is of far less frequent occurrence in woman than in man; a comparison between the numbers of internal cases proving this fact in a remarkable manner, and in cases of external aneurism still more so. It is very rare to meet with a popliteal aneurism in a female. Certainly, the more laborious habits and constant exposure to accident in the one sex may in some respects serve to account for this circumstance, but to those who know that in many places women are obliged to undergo at least as much hardship and fatigue, the explanation will be far from satisfactory. Again, it has been stated that certain pursuits of life predispose to aneurism, inasmuch as it prevails amongst coachmen and postilions, but there never has been even a plausible reason offered to explain this greater liability of particular callings. It cannot be the bent positions of the limbs of such persons, because many other classes, studious persons for instance, maintain similar postures for a longer time and with greater frequency, yet is not aneurism common amongst them. Neither will the sudden stretching of the limb by pressing the foot against the stirrup or footboard in managing the horses throw any light upon the subject, for it is found by experiment that no force will rupture a healthy artery short of what would also tear asunder the ligaments of the adjacent joints. Allowing, therefore, the accuracy and truth of these observations, their explanation is still to be sought for.

Some have supposed that old age, and the deposit of earthy material which is formed in the arteries at that period, are predisposing causes of aneurism; yet, if this was the case, the disease should be very prevalent indeed among those advanced in life, whereas it is in reality almost as rare as in infancy or early youth. Of fifteen cases of large aneurism operated on, only two had exceeded the age of forty years, the average of all being but thirty-one and a half; and if a larger number of cases (inclusive of the internal forms of the disease) were collected and compared, it would probably be shewn to be considerably less. With respect to the earthy deposit alluded to, it is found between the fibrous and internal coats closely adhering to the latter, from which it can scarcely be separated: it is disposed in thin laminæ or plates of different sizes, the largest being seldom greater than a spangle, and these earthy spots are distinct and separate, not running into or connected with each other, and never encircling the vessel with an uninterrupted bony ring. They are supposed to render an artery friable and brittle, and therefore to predispose to aneurism, and have been considered by some to be the products of arterial inflammation. Unfortunately the origin and progress of this earthy degeneration have not yet been satisfactorily traced. Scarpa* seems to regard it as arising from the same cause that produces the steatomatous deposit, and states that it cannot be said to be proper to old age, as it is sometimes met with in patients who are not much advanced in life. I have seen these earthy depositions in the aorta of a female not twenty-five years of age, which was also highly inflamed and covered with spots of soft steatomatous deposit, but still that is far from proof of its being the product of active inflammation, or of its rendering the artery weak or disposed to aneurism.

Of any number of subjects above the age of sixty brought into a dissecting-room, three-fourths will be found with this earthy degeneration in some of the arteries, yet the infrequency of aneurism amongst old patients has been already remarked. Again, this deposit has been seen in the sac of a true aneurism, a circumstance that would shew it did not greatly interfere with the distensibility of the arterial tunics or render them more friable,

* A very curious case of this description is related in the Dublin Hospital Reports, vol. v. p. 167.

* On Aneurism, page 90.

and, lastly, a large and important vessel in this condition has been tied without its being crushed or broken down short, and being followed by consecutive hæmorrhage. From these observations some reasonable doubt may be entertained of these deposits being the result of inflammation, more particularly as, at the period of life alluded to, there is an evident disposition to the formation of earthy deposits in many structures and organs as well as in the arteries.

When a large aneurism runs its course with great rapidity, an opportunity is frequently afforded of observing a condition of the vessel most favourable to the production of the disease, and which therefore may be considered as one of its direct or immediate causes. The vessel in this case, on being slit up, exhibits its internal lining membrane less smooth and polished than in its natural state; its colour is changed to a deep roseate carmine, and it separates from the subjacent fibrous coat with comparative facility. This latter structure is also changed in colour, but not to so bright a red as the other. Between these coats, but more closely attached to the internal, (for they peel off with it,) are numerous specks of a soft steatomatous material of a white or pale grey colour, presenting, on a superficial inspection, somewhat of the appearance of the calcareous deposit already spoken of. An artery in this condition has lost more or less of its elastic properties; it is distended, and its calibre increased equally around. As the arteries are always full, the impulse of every new wave of blood driven on the greater quantity contained within the distended vessel increases its apparent pulsation, for it is in the diastole or expanded condition of the artery that the pulse is felt. This loss of elasticity must obviously weaken the vessel, and cause it to be less resisting: a fact that can be proved by experiment after death, when an artery so circumstanced will be found to yield and tear under a distending force that would have little effect on it if in health, and will explain how an apparently trifling exertion may produce aneurism in one man, whilst numbers of others exposed to similar or even greater violence escape safe and unharmed.

If arteritis can be justly considered as an immediate cause of aneurism, it follows that any thing tending to produce this condition of the vessel will predispose to the disease. An investigation of the natural history of this affection would, therefore, prove equally useful and interesting, but as yet a sufficient number of facts have not been collected from which any useful practical induction can be drawn. The experience of an individual cannot be sufficient to establish a fixed and general position, but may be valuable if it induces others to a similar line of investigation, in order to its being verified or contradicted; and from a minute attention to the previous history of several cases, I have frequently been able to connect intemperance, particularly in the use of spirituous liquors and repeated or ill-conducted courses of mercury, with the production of arteritis. How far these can explain the comparative infrequency of the disease in females and its prevalence amongst men subject to exposure, and too often of reckless and dissolute habits, must be determined by future observation; but, in corroboration of the latter part of this opinion, it may be remarked, that few old persons are subjected to a course of mercury that do not perish shortly after by the bursting of a bloodvessel,—of apoplexy, or hæmoptoe most frequently.

When arteritis has proceeded to the extent of producing these steatomatous deposits, if aneurism is not inevitable, it is certainly very likely to ensue. In some instances the loss of elasticity is so great as to cause all the coats of the vessel to yield and become distended into the sac of a true aneurism: in others, (and far more frequently) the process of ulceration commences, the lining membrane covering one of these spots first becoming soft, then exhibiting a distinct ulcer which proceeds from within, eroding the middle coat either through its entire thickness to the cellular, which is then easily distended into the aneurismal sac; or so far as that it shall be likely to give way and tear under a trifling shock, even under the impulse of the circulation. In the pathological collection of the medical school of Park-street, Dublin, there are preparations exhibiting these forms of aneurism and the different stages of dilatation, of softening, and of ulceration in the most satisfactory manner.

Circumscribed false aneurism. — When a person experiences a sensation as if something had given way or been torn within his limb, or even without such previous warning, perceives a small hard, pulsating tumour situated somewhere immediately on the course of a large or leading artery, it is to be suspected that an aneurism has formed. And this suspicion is confirmed, if the tumour becomes larger or smaller, according to the diastole or systole of the artery, or is diminished by pressure, or almost disappears if the patient should happen to faint. If pressure be applied on the trunk of the artery between the tumour and the heart, its pulsation ceases, its size is sensibly diminished, and it becomes soft and flaccid; if on the farther or distal side of the tumour, its size is increased, and its throbbing rendered far more evident. The pulsation is said to become more faint in proportion to the growth of the tumour, and this, though generally true, is not so universally, for this symptom will presently be found to be influenced by a number of circumstances, such as the blood within the sac being fluid or coagulated, the situation and depth of the tumour within the limb, and the coverings of fascia it may possess. In most instances there is a peculiar whizzing sound, plainly perceptible on applying the ear or a stethoscope to the tumour, termed by the French the "bruit de soufflet;" but its presence or absence is by no means pathognomonic, for it may be artificially produced by pressure on the trunk of any large artery.

On examining a circumscribed aneurism

after death or the removal of the limb, the artery should, if possible, be always slit up on the side opposite to that from which the tumour springs. The appearances of inflammation will probably depend on whether the aneurism be recent or of long standing, and obviously on whether it has been the result of accident or disease. Also, if it be recent, the aperture leading into the sac is generally well defined, circular, and circumscribed, its edges remarkably thin and fine: if, on the contrary, it is old, the aperture is large, smooth, and so even as to present an appearance as if the lining membrane had been prolonged from the artery into the sac. On cutting into the sac some fluid blood is usually found, and always a quantity in a state of coagulation. Besides, there is always more or less of fibrine, the remains of former coagula deposited in irregular laminæ, and varying in colour from a pale red or grey. The most external layers are closely fastened to the internal wall of the sac by means of large depositions of flaky lymph, from which, however, they can be separated by careful washing or maceration. This lymph thickens the walls of the sac, and imparts to them considerable firmness and resistance. The sac, itself, is most generally of an oval form, but to this there are some exceptions, amongst which the occasional occurrence of a *dissecting* aneurism is the most curious. This happens when the internal and middle coats having ulcerated or given way, the blood insinuates itself between the fibrous and cellular coats, detaching them from each other to a considerable extent, whence the disease has derived its name.* Such is an outline of the appearances on dissection, but they will avail little in explaining the nature of aneurism, unless combined and compared with the phenomena of the disease during life.

And, in the first instance, it must be recollected that the tumour is pulsatile, a quality that proves the entrance of a quantity of fluid blood, and its return back again into the artery by the resistance or reaction of the sac. It was this circumstance that principally led Fernelius to believe and to teach that aneurism consisted in a dilatation of all the coats of the artery, inasmuch as he could not understand how pulsation occurred if the tumour did not possess an elastic covering, and moreover imagined that if the blood was driven into a sac otherwise constituted, it must of necessity remain there and become coagulated. It is, however, unnecessary now to discuss the question as to whether the sac of an aneurism possesses elasticity or not, when it is daily observed that any tumour (an enlarged gland for instance) situated on an artery, and receiving an impulse from the heart, may communicate the sensation of pulsation, provided the skin and other elastic tissues covering it are sound. Nay, farther, it may be remarked that the pulsation of an artery, even with its elastic coat uninjured, is much more apparent than real, and when felt ab externo, is greatly influenced by the skin and its other coverings. It is a fact too well known to every operating surgeon to be for a moment controverted, that an artery when exposed exhibits nothing like the force of pulsation that it did before the skin was divided; sometimes it is difficult to ascertain it satisfactorily at all. The late Professor Todd has strongly pointed out this circumstance in his case of axillary aneurism, published in the third volume of the Dublin Hospital Reports, where he says, " For some time I could not be convinced that the feebly pulsating vessel, to which the point of my finger was applied, was really an artery of such magnitude as the subclavian ;" and similar observations could be adduced, if necessary, from other sources.

It is of little consequence, then, whether the aneurismal sac possesses an elastic covering proper to itself or not, the resistance of the external structures being sufficient to explain the phenomenon of pulsation, and the importance of the integrity of these structures in the progress and termination of the case is extremely interesting. If even a small quantity of blood was thrown at each pulsation of the heart into a yielding, unresisting bag, it must of necessity remain there, and in a very short space of time the accumulation would be enormous; but if there is a re-acting force capable of returning a portion of this blood and restoring it to the circulation, the accumulation and consequent growth of the tumour will be measured by the quantity of blood thus left behind. The volume of blood sent into an aneurismal sac must be proportioned to the aperture through which it has to pass, while the actual quantity lost must depend not so much on this as on the non-resistance of it and its coverings, and their incapability of returning the fluid back into the circulation. Hence the growth of external aneurisms is in general rapid or slow according as they have existed a greater or less length of time; for in old aneurisms the aperture into the sac is generally large, and the elasticity of the external coverings is weakened by over-distension.

The pathology of aneurism arranges itself under two distinct orders, one having relation to the open and bleeding artery, the other consequent on the hæmorrhage being internal. This latter circumstance is interesting to the surgeon, because the presence of the blood in the limb, the position it occupies, and the pressure exercised by it on the adjacent structures and organs, very often form the most prominent and important features of the disease, and nearly as frequently cause the destruction of the patient as the bursting and bleeding of the tumour. But the consideration of this part of the subject does not immediately belong to the pathology of the arterial system, to which these remarks are more particularly directed. To return, then, to the open or ruptured artery. The condition of the vessel is scarcely different from that of one wounded by a knife. It is a bleeding artery, and the same principle that is applicable to hæmorrhage under any other

* See Dissections of Aneurism, by John Shekelton, Dub. Hosp. Rep. vol. iii.

circumstances is also available here, for if a wound of this species of vessel cannot heal whilst its calibre remains open, neither can an aneurism be cured until the artery from which it springs is completely obliterated at the spot where the aperture into the sac exists. The complete closure of the vessel is to be accomplished by placing its opposite walls in contact and under the influence of such pressure as will occasion inflammation and the effusion of coagulating lymph,—a pressure that can be applied either *ab externo* by means of compress and bandage, or from within, by placing the blood in the sac in a condition that will admit of its perfect and complete coagulation.

Pressure on the tumour, if it could be exactly applied and firmly maintained, ought to succeed, and, in truth, has often been successful, particularly when the disease is consequent on a wound; but there are so many difficulties to be surmounted and dangers to be encountered in its use, that few entertain much confidence in it, and perhaps it never would be resorted to but from a dread of consecutive hæmorrhage after a ligature. A bandage, if applied with sufficient firmness to operate with rapidity, occasions such excruciating pain that it can scarcely be endured; and if loosely, it is liable to slip; and if even it does finally work a cure, the progress of the case is so protracted that many patients become wearied with the trial. Again, the large trunks of arteries throughout the extremities are generally accompanied by nerves and veins in such close apposition with them, that a compress can scarcely be applied to one without interfering with the other; and instances have occurred of dreadful mischief having been occasioned by interruption of the venous circulation in such cases, even in the course of one night. Finally, pressure has very frequently caused the rupture of the sac, and the aneurism, from being circumscribed, has suddenly become diffused; and if there was no other source of apprehension but the possibility of this latter occurrence, it should make a surgeon pause before he adopted so hazardous a mode of treatment.

Pressure from within is effected by removing the impulse of the heart from the blood within the sac for a sufficient time to permit of the sac becoming perfectly filled with blood, and for that blood to become coagulated. This object will be accomplished by interrupting the flow of blood under the impulse of the heart through the leading trunk of the vessel for a given time: in cases of small aneurisms forty-eight hours being sufficient, but the larger and older requiring a longer period. A ligature placed around the vessel between the tumour and the heart effects this purpose; but it does more than is requisite, for it divides its internal and middle coats, occasions the effusion of lymph and the obliteration of the artery there, and involves the risk of consecutive hæmorrhage afterwards on its final separation. To avoid these inconveniences, the *presse artere* of Deschamps and a number of other contrivances for arresting the flow of blood through an artery, and admitting of easy removal after the object has been accomplished, have been proposed and tried, but success has not been so great as to warrant their general adoption, and the operation by ligature is still very generally preferred. It may be applied either at the cardiac side of the tumour, when it acts in the manner above stated, or between the aneurism and the capillary circulation, in which case the principle of its operation is somewhat different.

In the former instance, when a ligature is applied to the trunk of an artery, the supply of blood to the limb below it is interrupted for a few moments; the aneurism loses its pulsation, and sinks and diminishes in size more or less according as its contents had been fluid or coagulated. Soon the blood begins to flow through the collateral branches, and enters the aneurismal sac also, but it passes into it slowly and without impetus, and no part of it is again forced back into the circulation. It coagulates and comes to press upon and close the ruptured vessel, which is soon obliterated by lymph, and in process of time becomes degenerated into little more than a ligamentous cord. A beautiful illustration of this entire process was seen in Mr. Crampton's case* of ligature of the common iliac artery. The patient had two aneurisms, one of very large size at the groin, the other in the popliteal space of the same limb, firmer, and of much smaller dimension. A ligature of catgut was placed round the common iliac, which either rotted or by some accident became detached on the sixth day: the pulsation returned in the larger tumour, which soon afterwards burst, and the patient perished. The sac of the popliteal aneurism being so much smaller had time to become perfectly filled with blood, which was there coagulated and firm. The ligature had accomplished all that was necessary for it, and the cure would have been complete even although the ligature had loosened—whilst the opposite was the fact with reference to the larger tumour.

Sometimes, soon after the ligature has been applied, pulsation reappears in the tumour. This must always be considered as an untoward circumstance, but does not necessarily involve the failure of the operation; for it may take place under two different conditions of the parts. 1. In aneurisms of very long standing, in situations where there is a free and extensive collateral circulation, probably increased by the pressure of the tumour. In these the pulsation does not return for some time after the vessel has been tied, and is never so strong as before the operation. It may continue for several days, but gradually diminishes in force, and at last ceases. The progress of the case then resembles that of the ordinary forms of the disease, except that in this the cure is much more protracted. Apparently, such was Sir A. Cooper's first successful case † of ligature of the common carotid artery, as also the case of carotid aneurism published in the fifth volume of the Dublin Hospital Reports.‡ It is not un-

* Medico-Chirurg. Transactions, vol. xvi.

† Medico-Chirurg. Transactions, vol. i.

‡ Page 208.

likely that Mr. Turner's case of aneurism in the fore-arm, in which he secured both radial and ulnar arteries, was of a similar description also. 2. Where by an irregular distribution there exist two trunks in the limb, both conveying blood to the aneurismal tumour. Sir C. Bell had a case of popliteal aneurism in the Middlesex Hospital, in which, just below the origin of the profunda, the femoral artery divided into two branches of nearly equal size, which ran parallel to each other until they arrived at the spot where the artery perforates the tendon of the triceps muscle, and there they united again. Only one of these was tied, and although the pulsation in the tumour ceased for a moment, yet it soon returned, and never disappeared until the patient's death, which happened a few days afterwards, from erysipelas. A preparation of a similar distribution is preserved in the Museum of the Royal College of Surgeons in Dublin;* and it is quite clear that where such exists in an aneurismatic limb, the securing of one of the trunks could produce no benefit.

It has been already stated that one of the effects of the ligature on an artery is the eventual obliteration of the entire calibre of the vessel between it and the nearest collateral branch at each side, and, therefore, it might be supposed that if it be tied immediately close beyond an aneurismal sac in such wise that no branch shall intervene between the cord and it, the whole of the canal to the next branch, including the spot where the rupture had taken place, ought to become obliterated, and the aneurism thus be cured. This is the principle that led to the performance of the operation of tying the artery at the distal side of the aneurism. It was (I believe) originally proposed by Delpech, and put in practice by Desault, but the termination of the case gave little encouragement for future trials, and it fell into disuse until of late years, when it has again been tried in England, and still subsequently by Mott, in New York, but not with a success to justify its general adoption. There is but one artery in the body (the common carotid) so circumstanced as to answer the design of the operation; and even in this, if the smallest and most trifling branch happened to intervene between the aneurism and the ligature, it must defeat the principle of the operation altogether, and perhaps tend to aggravate the disease.

True aneurism.—Two different pathological conditions of an artery have been regarded as constituting this disease; one in which the entire circumference of the vessel is distended, forming a tumour of an oval shape, pulsating strongly during life, and not containing coagulated blood: the other is where all the coats of an artery at one particular spot are dilated in such wise as to form a sac springing from the side of the vessel, and containing blood withdrawn from the circulation, and in a state of coagulation. Perhaps it would be more correct to regard the former of these as a state of vessel predisposing to the formation of a false aneurism, whilst the latter, presenting during life the same phenomena, and curable on the same principles that have been already laid down, must be considered as offering truly a specimen of the disease.

When in consequence of arteritis, or from any other cause, the elasticity of the arterial structure becomes impaired or weakened, a dilatation of the vessel at the spot so debilitated ought to be the result; and this probably takes place in all arteries previous to the formation of idiopathic aneurism. But the circumstances that determine an artery to become dilated rather than to ulcerate are very obscure, for the same morbid appearances in the vessel are observed to precede both. In the eleventh number of the Dublin Journal of Medical Science there is an account of two cases of internal aneurism, one formed by ulceration of the internal and middle coats of the artery, which burst into the œsophagus; the other, evidently by dilatation, which destroyed the patient by pressure on the trachea: and in both the aorta exhibited the same appearances of inflammation and steatomatous deposit beneath the lining membrane. The preparations are preserved in the collection of the school in Park-street, and as showing this pathological fact are extremely satisfactory. Again, it is not easy to say what dilatations should be considered aneurismal or not. The aorta, in a great proportion of subjects above the age of forty, is dilated; yet such dilatation is not regarded as an aneurism. Other arteries present a similar appearance occasionally; and a case occurred not very long since in the Meath Hospital, in which all the arteries of the inferior extremities in an aged man were dilated to more than twice their natural calibre. These vessels were found after death filled with coagulated blood, yet as the fluid seemed to circulate through them during life, and the patient never experienced any inconvenience, it is difficult to admit them as specimens of true aneurism. On the other hand, nearly at the same time, a man died in another hospital who for years had a small aneurism of the femoral artery, with every observable symptom of the disease except that the growth of the tumour was unusually slow; and on dissection this appeared to have been a species of true aneurism, caused by an equal dilatation of the entire circumference of the vessel, and did not contain coagulated blood. It would seem, then, impossible to pronounce during life on the real nature of an aneurismal tumour, nor is it always easy to demonstrate it after death.

In most instances of aneurism, particularly those of long standing, the edges of the aperture into the sac are smooth and even, and the lining membrane seems to be prolonged into it. The internal wall of the sac is so thickened, and all the parts so matted together and confused by depositions of lymph and fibrine, that the appearances altogether become so deceptive as almost to countenance the old opinion as to the pathology of the disease. Professor Scarpa, who principally opposed the doctrine of aneu-

* There is a similar preparation in the Museum of St. Bartholomew's Hospital.—Ed.

rism by dilatation, was obliged to support his opinions more by argument than by facts demonstrable by dissection; and although later investigations, particularly those of Mr. Hodgson and Mr. Guthrie, have satisfactorily proved the occasional existence of both true and false aneurism, yet it must be a favourable case and patient examination that will enable the morbid anatomist to exhibit its nature and structure without possibility of error. When cases of inflamed or diseased artery are seen, complicated with aneurism, and the same depositions are observed in the artery and in the sac, it proves beyond doubt the identity of structure in both. Thus, if an aorta be found studded over with specks of a soft steatomatous deposit situated between its internal and middle coats, and if on one side of it an aneurism is placed, in the sac of which, throughout its entire extent, the same appearances and the same deposit are observed, it follows that the same structures must exist in both, and that one is a prolongation of the other. One of the cases already noticed as being a true aneurism, that destroyed the patient by pressure on the trachea, exhibited such evidence of its nature: and a similar one, but still more satisfactory, occurred in the person of a gentleman, who died some years since. This patient had laboured under some anomalous cerebral symptoms, and on inspecting the brain a small aneurismal tumour was seen at the bifurcation of the basilar artery, in the sac of which were found the same kind of earthy depositions that pervaded all the arteries of the body—the same so generally observed in the arteries of aged persons. These examples are sufficient to prove that aneurism by dilatation may exist, and perhaps its occurrence in the aorta and larger vessels is more frequent than has been supposed.

During the past spring two opportunities occurred of examining into the nature and condition of aneurism, both in its early stage and long after it had been apparently cured by operation. They were, probably, both examples of what has been termed true aneurism, although unquestionably all the coats of the artery were not engaged: and as the morbid appearances have not been hitherto described, it may be useful to take notice of them here.

A man was admitted into the Meath Hospital, with popliteal aneurism in each ham: one of these had existed for several weeks; the other was of very recent occurrence. The limb in which the older and larger one was situated was first made the subject of operation, the femoral artery was tied, but the patient died on the sixteenth day afterwards, of venous inflammation, the ligature on the vessel still remaining firm and undetached. On examining the aneurismal tumour externally it appeared of an oval shape, and to have been formed by the gradual expansion of all the coats of the vessel. On being cut into, however, it was found that the lining membrane was wanting throughout the entire extent of the sac, the edge of it terminating sharply and abruptly, above and below, at the junctions of the tumour with the more healthy parts of the vessel, and being as accurately defined as if made by a careful dissection. The fibrous coat was evidently continued into the tumour, which seemed to be formed of an expansion of it and the cellular. It was, moreover, otherwise diseased, being thickened, greatly softened and thrown into irregalar rugæ or folds, the interstices between which were filled with coagula of lymph or fibrine. As the sac of this aneurism was in a state of suppuration, the deficiency of the lining membrane was attributed to that circumstance until the other aneurism came to be examined when the same appearances were observed. The second tumour was not so large as a walnut and evidently formed by the gradual expansion of the fibrous coat, for the abrupt terminations of the lining membrane at the healthy extremities of the artery were still more exactly defined.

The other case is even more interesting, because it exhibits a cure of aneurism after operation in a manner that has not been described, the principle of which it is not easy to understand. A man was operated on by Mr. Collis, in the Meath Hospital for popliteal aneurism on the 22d of January, 1831. The ligature came away on the seventeenth day, the tumour diminished; in short, every thing went on well and the patient left the hospital perfectly cured. So far as the aneurism was concerned, he remained healthy and free from inconvenience until his death, which happened in March 1835, from fever, and such an opportunity for pathological inquiry was not neglected. The tumour which had been originally of the size of a turkey's egg, was found to have diminished to little more than that of a walnut: externally it felt hard and as if completely solidified: on being cut into, however, neither artery nor sac was obliterated, the latter being occupied by a coagulum of a deep red colour, through the centre of which was a canal of a sufficient size to allow the blood from the portion of the artery above the tumour to flow freely into that below it. It seemed as if the current of blood through the sac had never been interrupted, the only effect of the former ligature having been the removal of the impulse of the heart from it. This aneurism *appeared* to have been a true one, so far as the fibrous and cellular coats were concerned, but the fact could not be so satisfactorily demonstrated as to admit of no dispute; however, the absence of the lining membrane and its sharp and abrupt terminations at the healthy portions of the vessel were sufficiently obvious.

If it be difficult to demonstrate the nature and constitution of the small and recent aneurism, it becomes impossible when the tumour has attained to a considerable size. It seems probable, however, that the arterial structures will not long endure this state of unnatural distension, and they either ulcerate or tear in their internal and middle coats. A mixed aneurism will thus be formed, having its sac at first composed of all the structures of the artery, and subsequently in the largest portion of its circumference, of the cellular coat alone. The long continuance and gradual increase of some aneurisms, as contrasted with their sudden and rapid growth afterwards, have been explained on this supposition.

Diffused aneurism.—An aneurism is termed diffused when the blood, removed from the circulation, is not confined within a pouch or sac, and therefore passes in every direction throughout the cellular tissue of the limb. This may be occasioned by the rupture or ulceration of an aneurismal sac, but far more frequently by some violence applied to the artery itself in such a manner as to open its cellular as well as its other coats. Thus a spicula of a fractured bone, or a pointed sequestrum, in coming from a necrosed limb, may produce the disease; but the most common examples that fall under a surgeon's observation are furnished by awkward or ignorant persons in their attempts to perform the operation of phlebotomy. In the latter case there is an external wound communicating with the injured vessel, and then it also presents a familiar illustration of traumatic aneurism.

When the blood is thus diffused throughout the cellular tissue, there is always the greatest danger; not so much from the loss of a large quantity to the circulation as from the rapidity with which a limb so circumstanced runs into a gangrene,—a rapidity so great that the mortification either is not or seems not to be preceded by inflammation, and its occurrence is often the first notice a surgeon receives of the extent and nature of the accident. When the injured artery lies deep and is covered by a dense and resisting fascia (as in the instance of the posterior tibial artery being ruptured by a blow), it may bleed for some time without affording any indication beyond the pain and tension complained of by the patient, and a slight tumefaction of the limb. When, however, the fascia has yielded or sloughed and permitted a more extended diffusion of the blood, the part becomes swollen, glassy, and œdematous, pale if the blood did not occupy the cellular tissue underneath, but of a livid colour, like that of a bruise, if it does. The joints in the neighbourhood are kept flexed, and any attempt at motion gives intolerable pain. In a very short space of time circumscribed spots of gangrene appear, which, on separating, permit masses of very dark coagula to protrude, accompanied by an oozing, or perhaps, a flow of arterial blood, under which a patient will very soon sink. And it may be, the real nature of the case has not been suspected until this blood has made its appearance. Doubtless, if a diffused aneurism has been occasioned by a wound, the rush of blood at the moment, its colour, and the difficulty of controlling the hæmorrhage will point out what has happened; or if there had been a circumscribed aneurism that on a sudden lost its defined character while the limb began to enlarge above and below it, there would be good grounds for suspicion; but in any other case it is so difficult to separate the pain and tension and the other symptoms from those which might naturally supervene on a severe injury, that the appearance of a tendency to gangrene is too often the first circumstance to create alarm. There are many symptoms in which the diffused aneurism differs from the circumscribed, that render the diagnosis of the former particularly difficult. It has been already stated that the "bruit de soufflet" is, even when present, not a pathognomonic symptom, and if the vessel lies deep it is not to be heard at all. Pulsation of the tumour, the most satisfactory symptom of an aneurism, is generally absent, and when otherwise, is very weak, fluctuating, and indistinct. To those who reflect that the effused blood is thrown out amongst inelastic and unresisting structures, that no portion of it is returned to the circulation, but that it lies a coagulated mass amongst the surrounding cellular tissue, the absence of these symptoms will not require explanation.

Traumatic aneurism.—But if, as very frequently happens, the accident that caused the aneurism has also created an external wound communicating with the injured vessel, and permitting the escape of a portion of the blood through it, although still a diffused aneurism, the leading circumstances of the case are essentially altered. This is the form of disease termed by the French traumatic aneurism, the name having reference not so much to the fact of its having been produced by violence, as to the co-existence with it of a solution of continuity in the skin and other structures external to the vessel. Thus, although an aneurism may be caused by the prick of a lancet in the bend of the arm, or by a bayonet-wound in the thigh, yet if the external wound is healed, or, being unhealed, if it is so oblique or devious that the blood flowing from the artery does not escape from the limb, it may not be called traumatic, whilst a common popliteal aneurism that had arisen spontaneously, if it is accidentally opened, assumes the character just designated. The chief peculiarity of this case, then, is the external wound, and if it be conceded that it is the resistance of the unyielding structures that presses the coagulum against the vessel, and thus accomplishes the cure of those forms of aneurism already described, it will be seen that a material part of the process must be deficient, and, therefore, that the principles applicable to the former cannot be made available here.

In order to the proper understanding of this part of the subject, it will be necessary to take a familiar case for illustration. A person in attempting to open a vein in the arm strikes his lancet into the artery, and is, perhaps, unconscious of the extent of the mischief he has occasioned. The arm is tied up, but it swells and becomes intolerably painful. When the bandage is removed, the wound is found not to have united, and a coagulum is probably seen plugging it up, which loosens occasionally and allows the escape of a considerable quantity of red and florid blood. In the meantime the diffusion throughout the limb is extending in every direction, and the hæmorrhages from the external aperture are more frequent. If this case is treated by ligature at a distance from the situation of the aneurism, although the patient may appear relieved at the moment, that relief is but delusive. The blood may coagulate, but being unsupported by any external resistance, it cannot make sufficient pressure on the orifice of the bleeding vessel. Fresh blood is carried round by the collateral circulation, and as it constantly oozes from the punctured artery, it disturbs the coagulum in the neighbourhood, and bursts out into new and repeated hæmorrhages until the surgeon is obliged to end where he ought to have begun, by cutting down (if he has still the opportunity) directly on the injured part of the vessel, and tying it above and below the aperture. The great difference between the traumatic aneurism and the other forms of the disease is, that in it the hæmorrhage is external as well as internal, and that the coagulum within the limb being unsupported may press outwards through the wound more freely than inwards upon the vessel. The coagulum, therefore, is not available in the cure, and the treatment must have reference to the wounded artery alone. If the radial artery was opened and bleeding freely from the external orifice, few surgeons would think of taking up the brachial high in the arm, knowing that the inosculating branches would still supply abundance of blood to the wound, and although the pathology of traumatic aneurism is somewhat different, inasmuch as a portion of the blood lost still remains within the limb, yet the principle of treatment is unchanged.

It may be objected that in very many instances of traumatic aneurism success has attended the application of a ligature on a distant part of the artery; but every one of these cases will require to be accurately examined before the treatment here laid down can be impeached. The definition of traumatic aneurism must be borne in mind, and that it implies not only the existence of a wound, but of one through which coagulated blood may protrude and fluid blood may trickle. The only case in which such practice could succeed is, where, after the ligature had been tied, a sufficient degree of pressure *ab externo* could be maintained to lay the opposite sides of the wounded artery together, and produce sufficient inflammation to procure its complete obliteration,—in short that it shall effect that which the resistance of the skin and fascia and other superincumbent structures would have accomplished in a limb less injured. Such pressure as this must occasion intolerable suffering; and experience has proved, in numerous instances, how little reliance can be placed on it.

Secondary hæmorrhage.—Hitherto the application of a ligature has been noticed only as a curative process, its advantages have been discussed, and the manner in which it may be supposed to operate explained; but it has been also stated that "the ligature is in itself not infrequently a cause of great and fearful mischief," and as the consideration of the different cases that might require the operation has been just concluded, perhaps this may be a fit opportunity for examining into the nature of these unfavourable cases. Secondary or consecutive hæmorrhage occurs, as its name implies, at some period subsequent to the application of the ligature, and the blood flows from the place where the vessel has been tied. In many instances the patient has a kind of presentiment of that which is about to happen, and becomes restless, uneasy, and agitated; in other instances there is not the slightest warning, and the first notification of the mischief is the appearance of the dressings soaked in blood. In general it has been stated that it is on the separation of the ligature that this bleeding takes place, but this is not the fact, for commonly it happens whilst the cord is fixed and firm, and three or four days before its fall ought to be expected. The longer the ligature remains, provided no nerve or fascia had been included with the vessel, the safer the patient is, and it must be rare to meet with secondary hæmorrhage after the cord has become detached and been quietly withdrawn. It is remarkable that the blood comes from the inferior portion of the artery; it wells up abundantly from the bottom of the wound, and never flows with a gush or per saltum; it is easily restrained by pressure on the bleeding orifice; and if such pressure is accurately applied, and can be maintained during a very few days, the cure is permanent, and the patient would be safe but for a number of collateral circumstances, which, however important in the management of the case, form, properly speaking, no portion of the pathology of arteries.

Various causes have been assigned as producing secondary hæmorrhage, the chief of which is the too extensive detachment of the vessel from its surrounding connexions during the operation, an opinion that I cannot think is borne out by observation. If it is supposed that this dissection of an artery is injurious by depriving it of its vascularity, and diminishing its supply of nutrient blood, the result should be analogous if not exactly like that which takes place when the vessel is deprived of its cellular coat from any other cause, that is, a slough should form on it, on the separation of which the hæmorrhage should occur violently and with a gush. An illustration of this is familiarly observed in the phagedenic ulceration of buboes in the groin, where the artery for a time appears to resist the destructive process, and lies denuded like a white cord at the bottom of the sore; but one or more black spots form upon it, which are really specks of mortification, on the detachment of which the bleeding commences with awful violence. Perhaps consecutive hæmorrhage does occasionally occur from the burrowing of an abscess along the coats of an artery, an example of which is on record in Mott's case of ligature of the innominata, in which the bleeding occurred ten days after its removal, was so violent from the first as to be with much difficulty restrained, and destroyed the patient on the day but one afterwards. But it may be observed that the phenomena attendant on these cases are different from those already described as characteristic of the common forms of the accident—that they usually occur at a later period, even long after the separation of the ligature might have inspired confidence in the result, and they are evidently more hopeless, for neither pressure nor ligature can here be of the slightest avail. Farther, to appeal to experience, the best and surest foundation of every scientific principle, is it not a matter of daily observation that this much-dreaded insulation of the artery can have but little effect on the ultimate termination of the case, as operations performed in this respect in the most bungling and clumsy manner occasionally end well, whilst the utmost caution in not exposing more of the artery than will barely permit the passage of the ligature cannot ensure the patient from secondary hæmorrhage?

When the bleeding is occasioned by any defect in the operation, such as tying the cord too loosely, including adjacent structures, &c. it usually appears so early as from the third to the fifth day after the operation, and there is another form of early consecutive hæmorrhage that occurs in consequence of the artery itself being inflamed or otherwise diseased at the time of the operation. An example of this is too often met, when, as a means of controlling consecutive hæmorrhage, a fresh ligature has been tied on the trunk somewhere higher up or nearer to the heart. It has been remarked by Dupuytren, that an artery under such circumstances is in a most unfavourable condition for an operation; it is surrounded by cellular tissue in a state of inflammation, in which it participates; its coats are rendered so brittle that they break down immediately under the ligature, and the hæmorrhage returns in a few hours.* It is worthy of remark that in this case also the bleeding comes from the orifice of the vessel below the ligature; indeed, in all cases of divided artery, whether by a cutting instrument or by a cord, the remedial process seems to be different in the two fragments, being far more perfect in the upper. On this point the statements of Mr. Guthrie are most valuable because founded on extensive observation, and he remarks in the case of an artery, the bleeding from which had ceased of itself, that if it recurs it is more likely to proceed from the lower than the upper portion. This latter fact is the more important as it bears upon another supposed cause of secondary hæmorrhage, namely, the state of tension in which an artery inclosed in a ligature is necessarily placed.

Many years ago it occurred to Mr. Abernethy that, "as large arteries do not ulcerate when they are tied upon the surface of a stump after amputation, it would be right to tie them in cases of aneurism as nearly as possible in the same manner and under the same circumstances." It is familiarly known that he recommended for this purpose the application of two ligatures with the division of the artery between them; and he argues that the divided portions would be like the large vessels on the surface of the stump in possession of all their surrounding connexions, whilst they are left in a *lax state* in consequence of their division. But the cases after all are not analogous, because in the stump there is no inferior portion of vessel from which it has been seen the chief cause of apprehension arises—it has been cut away, and only the superior remains, from which it is rare to meet with hæmorrhage under ordinary circumstances. In Mr. Abernethy's operation it is only the upper division of the vessel that bears analogy with the artery of the stump, and the insufficiency of the removal of the tension in preventing hæmorrhage from the inferior is proved, first, by the fact that consecutive hæmorrhage occurs in cases that have been thus treated proportionally as often as in others; and, secondly, by Mr. Guthrie's observation that in the case of a wound there is no tension: the artery has been fairly divided, and its surrounding connexions are undisturbed; yet the bleeding, having ceased spontaneously, or, in other words, having been controlled by the power of nature alone, may recur, and when it does the blood flows from the lower orifice.

Others have believed that the accidental position of a collateral branch near to the ligature might be a cause of consecutive hæmorrhage by interfering with the formation of the internal coagulum. I have already stated that the importance attached to this coagulum was greater than it deserved; and it will be only necessary here to add, that I have tied the common carotid artery within an eighth of an inch of its origin from the innominata without the slightest ill consequence from that circumstance.

It has been pretty generally believed that in those cases which have ended favourably, a mild, healthy, and mitigated process of inflammation had been established which terminated in the effusion of lymph and the obliteration of the vessel, whilst in the unfavourable the inflammation was more violent and ran into ulceration. Nothing is more familiar than to hear of the ulceration of an artery in connexion with and as the cause of secondary hæmorrhage, yet the existence of such ulceration is very questionable. Arteries are not prone to ulcerate. It has been shewn that in the midst of phagedenic destruction, the artery escapes for a length of time, and when it is attacked, it is rather by mortification: and the appearance of arteries traversing in safety the cavities of tubercular abscesses in the lungs, where they have lain for weeks or months bathed in purulent matter, should make us hesitate in speaking so boldly of ulceration in these structures. The fact, as observed on dissection, appears to be quite otherwise, and the hæmorrhage to be occasioned not by a hyper-activity of inflammation tending to ulceration, but by an absence or failure of the process altogether.

As persons, the subjects of consecutive hæmorrhage, seldom die (at least in this country)

* Leçons Orales, tom. iv. p. 573.

of actual loss of blood, it is not easy to procure a dissection which can satisfactorily shew the condition of the vessel at the moment it begins to bleed, and no subsequent examination can be relied on, because the pressure or other means used to stop the bleeding may in the course of a very few days alter the appearances completely. I have availed myself of every opportunity that occurred, and state the results, not with the presumptive hope of being able to establish any general principle, but to excite others to inform themselves on every case favourable to the further prosecution of the inquiry, and, perhaps, in some respects to justify the opinions I have formed. It is worthy of remark, that secondary hæmorrhage occurs much more frequently in the arteries of the lower than of the superior extremities or of the neck, and all the specimens I have examined were of the femoral that had been tied from half an inch to an inch and half below the profunda. In all, the portion of the artery above the ligature gave indications of inflammation extending nearly as high as the common iliac; the lining membrane more or less vascular; the portion of the vessel between the ligature and profunda of its natural size or slightly diminished; its cavity occupied by the remains of a coagulum. Above that point the calibre of the trunk was evidently increased, and the texture of its coats less resisting. The inferior portion resembled a vessel simply cut across, its calibre diminished, its internal coat discoloured, its divided edge smooth and even, not rough, jagged, or irregular, as would probably be the case if it had been the seat of ulceration.

When a ligature is tied tightly round an artery, every thing included within its noose is killed, but this is only a very small ring of the cellular coat, the internal and middle being as completely divided as if it had been done with a knife. When the absorbents have detached the connection of this ring with the remainder of the cellular coat, there is nothing (so far as the vessel is concerned) to retain it farther, nor is it of use in preventing hæmorrhage: it might be withdrawn, only that being entangled in lymph or granulations from the adjacent parts, such a proceeding would disturb the divided vessel before the curative process was complete. This process is in some instances, perhaps, never attempted in the inferior portion, although such a deviation from the usual course is probably not frequent; when it does happen, the cure is more tedious and longer of accomplishment, and when interterrupted prematurely, of course it is from this portion that the blood is poured out.

Whatever the process is by which the extremities of the two segments are closed, it is certainly not the same in both. This fact I was enabled to verify in one of the cases already alluded to,—namely, that of the man who died on the sixteenth day after the operation for popliteal aneurism, and whilst the ligature still remained undetached from the artery. The vessel was carefully removed from the body, and on being slit up, the lining membrane of the portion at the cardiac side of the ligature was of a pale yellow colour and nearly of its natural appearance, with the exception of one or two broad spots of a very light pink colour. A large coagulum extended upwards from the seat of the ligature, the base of which was attached to the lymph situated there. The ligature was still firm, but on attempting to tear it away, the lower portion of the vessel easily separated from it, leaving it still fixed firmly on the upper section: a circumstance which explained a fact I had frequently witnessed, that of secondary hæmorrhage occurring before the final separation of the cord. Below the spot where it had been tied the vessel appeared to be of a deep pink colour approaching to carmine, the seat of which colouring matter was in the cellular tissue between the fibrous and internal coats. This cellular substance seemed to be hypertrophied and largely congested with blood, whilst it caused the lining membrane to be thrown into transverse rugæ or folds. On pulling off this membrane, it was pale, transparent, and colourless—devoid of any proper vascularity: and on looking along the slit-side of the vessel the fibrous coat and the internal membrane were seen like white lines with the congested cellular tissue between them. *There was not a particle of coagulum either of blood or lymph in any portion of the vessels below the ligature.*

It may be objected that in this very dissection, the appearances would warrant a belief that a more active form of inflammation was present in the distal portion of the vessel, because of the deeper tint of colour and the superior thickness of the cellular tissue there observed. Such, however, was not the impression of those who witnessed the dissection. There was no result of inflammation visible after seventeen days, neither adhesion, nor suppuration, nor ulceration: there was merely a congested condition of the part—a condition not found in other structures or situations to lead to any of the usual products of inflammation.

An artery, the coats of which have been divided by a ligature, is subject to the same conditions as if it had been severed with a knife: its cavity must be obliterated from the wounded spot to the next collateral branch above and below. Now, the constitutional causes that can delay or impede this obliteration, if any, are not sufficiently known; but it is obvious that any local interference may (as in a case of open hæmorrhage) prove singularly perilous. During the first few days, whilst the continuity of the cellular coat is still unbroken, there is no cause for apprehension; but afterwards, any irregularity of diet, any excitement of the circulation, any unwary motion, any injudicious meddling with the ligature; in short, any one circumstance that can interfere with or disturb the operations of nature within the part before they are perfect and complete, will have a much more intimate connexion with the production of secondary hæmorrhage than any of the causes hitherto advanced. Hence it is, that the bleeding occurs some two or three days earlier than the period at which the ligature naturally separates and comes from the wound.

When the bleeding has commenced, it is a case of hæmorrhage from an open wound, and must be managed on similar principles, that is, pressure to a sufficient extent must be applied directly on the orifice of the vessel. I have never seen a second ligature applied on the mouth of the vessel, either in consequence of the difficulty of finding the artery in a wound swollen and matted up with lymph and granulations, or from an apprehension of the existence of such a diseased condition of its coats as would cause it again to break down under the cord. But I have frequently witnessed the effective operation of direct pressure, particularly in three cases, which occurred within the last few months, two of which were patients in the Meath Hospital, and all of whom recovered. In the application of this pressure, however, much caution is required. It should not be greater than is absolutely necessary to command the hæmorrhage; it ought to be maintained by means of some mechanical contrivance, and be independent of all bandages which are liable to stretch, to loosen, or to slip, and it should be removed the very moment this can be done with safety. If the bleeding has been perfectly restrained during three or four days, it is probable it never will return. The sequelæ of secondary hæmorrhage ought always to have been regarded as more important and more perilous than the bleeding itself. I have invariably found the wound to become the seat of unhealthy suppuration: very frequently abscesses form in different parts of the limb, and occasionally gangrene supervenes. It is sometimes difficult to connect any of these occurrences with a lesion of any structure within the limb; but too frequently the mischief can be evidently traced to the pressure being directed on the vein, and being either too forcible or too long continued.

Having thus, however imperfectly, sketched the pathology of the arterial system in connexion with the use of the ligature, it will be necessary to revert to other forms of disease, which have hitherto been postponed, in order to permit the introduction of the subject of secondary hæmorrhage, and that the practical arrangement of aneurism and its consequences, both fortunate and otherwise, might be as uninterrupted as possible.

Aneurismal varix.—In the year 1761, Dr. William Hunter* directed the attention of the profession to a disease that had not been before observed, one not indeed very formidable in its consequences, but exceedingly curious as to its exciting cause and subsequent progress. When an artery and vein lying in close contact are transfixed by a cutting instrument in such a manner that the aperture in one shall exactly correspond with that of the other; and when subsequent inflammation has so glued and fastened these apertures together, that, whilst a mutual transmission of blood between the vessels is freely permitted, not a drop will be allowed to escape in any other direction, a disease is formed, to which the discoverer gave the name of *aneurismal varix*. All and each of these several conditions are absolutely indispensable, and there are so many chances of their not being fulfilled in a case of wounded artery, that the infrequency of the disease may be easily explained. It does, however, occasionally occur, and for obvious reasons will most generally be found in the arm as a consequence of phlebotomy.

Soon after the infliction of the injury that has been the cause of the disease, a small tumefaction is observed in the vein; its appearance is irregular and knotted, but it is soft, yielding, and disappears on pressure. On laying the finger on it, a peculiar thrilling sensation is perceptible, and on applying the ear, a whizzing noise is heard, very much resembling that occasioned by a fly inclosed in a small paper bag. These phenomena disappear on either current of blood being interrupted by pressure on the artery above or on the vein below: at the same time that the tumour subsides a little, (though it soon regains its original size) and the peculiar noise is no longer heard. If the disease is allowed to advance uninterruptedly, the calibre of the artery above the point of communication becomes enlarged, but it is diminished below: the vein also enlarges chiefly in the direction of the current of its blood, rarely in the opposite, and then but very slowly. Another interesting circumstance is, that the peculiar thrill is heard and felt all over the dilated portion of the vein, at a distance from, as well as in the immediate neighbourhood of, the point of communication between the two vessels. It seldom produces any inconvenience that cannot be remedied by the use of a moderately tight bandage, and if thus managed in time never requires a severer treatment.

From the circumstance of pressure, either on the artery or vein, diminishing the size of the tumour and removing the thrilling sensation it imparted, it may be fairly inferred that both these phenomena are produced by the meeting of the two currents of blood, and their mutual resistance to the escape of either from its proper vessel. And further, it is obvious that if the disease should by any chance prove troublesome or alarming to the patient, its growth might be checked and its progress altogether stopped by permanently obliterating the canal of either the artery above or the vein below: but no operation that a surgeon would be justified in undertaking can remove the tumour, inasmuch as the blood still will continue to flow into and through the enlarged vein. The dangers of secondary hæmorrhage after an artery is tied, or of venous inflammation if the other vessel is tampered with, ought to inculcate the greatest caution, and it may be easily understood why in such cases Dr. Hunter thought it advisable not to interfere.

* Medical Observations and Inquiries, vol. i. and ii.

This disease must, in the great majority of instances, be the result of accident, and its probable situation has been already pointed out, but it is also possible that it may appear as an idiopathic affection without any previous violence. Some years since a young female applied at the Meath Hospital as an out-patient, in whom aneurismal varices existed between every artery and vein in the body that lay in a state of approximation to each other. In the neck, in several parts of the arms, the thighs, &c. the peculiar thrill and sound were remarkably distinct and plain. She did not seem to experience much uneasiness, nor could any probable exciting cause be assigned for such a singular form of disease. She had previously suffered from syphilis and been subjected to irregular mercurial treatment, but it would be scarcely fair to assume as the cause of a solitary specimen of disease in one individual, influences that operate so very differently on others.

Varicose aneurism.—When a vein and artery communicate with each other in a manner similar to that already described, excepting that an aneurismal sac formed of condensed cellular tissue and containing some coagulated blood is interposed between their orifices, the disease is termed a varicose aneurism. As this disease is generally the result of some accident in bleeding, as it occupies the same situation at the bend of the arm, and as the sac in that case never attains to any considerable size, it is difficult and frequently impossible to distinguish during life between the two affections: nor is the diagnosis of much importance, for as the pathological changes in the artery and vein, and the phenomena produced by them, are exactly the same, so will be the rationale of the treatment.

Some few years since, a patient was admitted into the Charitable Infirmary with a popliteal aneurism of the size of a child's head, and with all the veins of the limb, particularly of the thigh, enormously distended so as to appear like ropes twisted and knotted under the integuments. In every one of these veins the peculiar thrill and sound of aneurismal varix could be distinctly perceived. The account he gave of himself was this: he had a pulsating tumour in the ham for fourteen years previously, which gradually increased to its present size, until the veins began to swell, when the large tumour became stationary. He experienced but little inconvenience, and said he was able to walk eleven or twelve miles a day. He was frequently permitted to leave the hospital, and exhibited himself to several professional men for money. As he refused to submit to any treatment, and indeed no operation held out a prospect of much benefit, he was soon discharged. This man (I believe) still lives, and as he resides in a distant part of the country, perhaps the true pathological nature of a case so very interesting may never be ascertained. Could it have been that this was originally a case of popliteal aneurism that had burst into the popliteal vein? The position of this vein, and its very intimate connexion with the artery, cause it to appear to be a part of the sac of every popliteal aneurism, and it is not difficult to conceive that the tumour might have given way in this particular situation, and a communication been thus established between the artery and vein through the medium of the aneurismal sac.

It may not be unimportant to observe, that rare as these latter forms of disease are acknowledged to be, they are still more so in reality than is generally imagined. It often happens that a congeries of knotted and contorted veins forms a tumour strongly resembling the aneurismal varix in its external characters, and imparting similar sensations of thrill and sound. If one of these happens to occupy a situation favourable to the production of aneurismal varix, it might easily occasion a mistake, and perhaps it would be very difficult to point out a satisfactory diagnostic. I have seen two of these tumours dissected, which during the lives of the patients were supposed to have been aneurismal varices, in neither of which could the slightest communication with any neighbouring artery be discovered.

Aneurism by anastomosis.—The disease which was so named by John Bell, and by him first placed in the class of aneurismal tumours, has no title to such a position, unless that it forms a reservoir of blood, and occasionally exhibits the phenomenon of pulsation. But it materially differs in that the blood contained within it is fluid, is not withdrawn from the circulation, and therefore does not coagulate. The circumstances, however, of these tumours being increased or diminished in size by those influences which excite or depress the activity of the circulation, and of the leading trunks of the vessels supplying them having, however erroneously, been made the subjects of operation for their cure, serve to connect them in some respects with the pathology of arteries, and justify a passing notice of the subject here. This kind of tumour has also been called the nævus maternus or mother mark, because it so often appears from birth or at a very early age, and its shape, colour, size, or situation is explained by the mother on the supposition of some substance having been thrown at her, or from other causes of affright. It may, however, appear for the first time in more advanced life, in the form of a speck or pimple, which gradually enlarges until it constitutes a disease of a most important and sometimes dangerous nature.

The external characters of aneurism by anastomosis are somewhat varied, and have admitted of its classification under three forms apparently distinct from each other: 1. Where the mark or stain is merely cutaneous, does not increase in size, and is never pulsatile. These marks may be of different colours, sometimes red, sometimes of a brassy yellow, or perhaps brown; and as they occasion no inconvenience beyond the unsightliness of their size and situation, they can scarcely be considered as diseases. Indeed, if the common mole be admitted under this class of nævi, in many instances it seems to constitute a beauty rather than a defect. 2. Where the disease is situated in both the skin and sub-cutaneous cellular tissue. It appears as a patch, slightly elevated, of a red or purple colour, being generally of a brighter hue on the face or breast, and darker on those parts usually kept covered. The colour of the nævus also seems to depend on the quality of the blood with which it is altogether or principally supplied, as sometimes tumours are met with which might be termed venous aneurisms of this description, consisting evidently of veins indurated, knotted, and contorted on each other, increasing gradually, and never pulsatile; these frequently occur in different parts of the body of the same individual, and are always attended more or less with pain. The arterial nævus is, however, most intimately connected with the present subject. It sometimes presents an appearance as if irregularly granulated; more frequently is it smooth and velvety. The deep stain possesses a sharp and circumscribed edge, yet a net-work of minute vessels may be seen like an areola around it, conveying blood to nourish the tumour, and therefore forming an important part of the diseased structure. The tumour is increased in size and intensity of colour by every thing that accelerates the circulation—by exercise, intemperance, paroxysms of passion, and even by an elevation of temperature, and hence the supposed marks of currants and other fruits are said to grow red and ripen at the proper season. Its feel is doughy, and communicates a sensation as if it contained a jelly. It sinks, and is diminished by pressure on its surface, but immediately the pressure is removed it recovers its former level. It may be stationary for years, but the contrary is generally observed; its growth, however, is always irregular, being more rapid at one period than another. 3. The distinguishing characteristic of the third form of nævus is its pulsatility. It beats synchronously with the heart and arteries. When wounded, blood of a bright red colour flows from it, often in such abundance as to occasion syncope or even more dangerous consequences. As it grows larger, the skin gradually becomes thin; it bursts and bleeds; masses of coagula lie upon its surface, putrefying and occasioning the most unsightly appearance and most offensive odour. This is a condition that cannot endure long, the patient soon becomes irritable and weak, and falls a victim to that irregular, ill-formed hectic which is seen in every disease accompanied by extensive hæmorrhages. It is manifest that the distinctions between these latter forms of nævi are merely artificial; the second can be made to pulsate and to increase by heat or intemperance, the third can often be restrained by cold, by abstinence, and other means that debilitate the circulation.

The external appearances, however, yield no information as to the condition of the parts within, or the nature of this newly-formed structure; and on this subject anatomical investigation affords but little satisfactory knowledge. When a nævus is extirpated, it seems to consist of a mass of cellular tissue, collapsed and flaccid, which cannot be unravelled, and seems to bear no proportion in size to that of the tumour before removal. If it be cut away close to its defined edge, and without the extirpation of the zone of small vessels already described, the bleeding is frightful, and in very young children may be fatal, evidently shewing that these vessels are not endowed with contractility, and are a diseased and a new formation. If a nævus is injected, it only affords a swollen and unshapely mass of whatever material had been used, and throws no light whatever on the real pathology of the disease. Here, then, in the absence of demonstration, theory and conjecture are permitted, and all that is known, or supposed to be known, is only the fruit of speculation.

Bell supposed the tumour to consist of a congeries of cells, into each of which an artery and vein opened; that these cells increased both in number and in size with the growth of the patient, until they became immense reservoirs of blood; and, finally, that they became so distended as to burst and destroy life, as any other aneurism would, by a profuse discharge of blood. But still this explanation is defective, as showing nothing of the nature of the cells themselves, or why blood poured out into them should not coagulate as it would in any other cellular structure. It remained for Dupuytren to offer an ingenious and extremely probable hypothesis relative to these points, and he conceived the aneurism by anastomosis to be a "tissu erectile," analogous to that naturally found in many parts of the body.*

In the penis of man, and in the clitoris and mamella of woman, there is a particular structure, capable of receiving, retaining in a fluid state, and afterwards returning a given quantity of blood. These organs are provided with strong fibrous sheaths, that prevent their distension beyond a certain size, and are furnished with a number of nerves that preside over the circulation through them, and determine their conditions of erection and collapse. The abnormal "tissu erectile" consists of a cellulated structure, in itself of the same or a similar structure, but not being invested by a fibrous sheath or capsule, its growth is unrestrained, and the size to which it may attain has no limit; and as it has not a similar distribution of nerves, there is nothing to occasion either unwonted distension or collapse, and it is left solely under the influence of those causes that act upon the circulation. (See

* The late Mr. Shekelton of Dublin injected one of these tumours with wax from a large artery in its vicinity, and corroded away the animal matter by immersing it in a weak acid solution, by which it was shewn to consist of a congeries of vessels arranged in a retiform manner, dilated at some points and contracted at others. An able and interesting paper was read on this subject, and on the tortuosity of arteries generally, to the medical section of the British Association, which lately met at Dublin. The great attainments of its author (Mr. Adams) in pathological science lead us to look, not without some degree of impatience, for the full publication of the paper, of which but an imperfect report has appeared in the Dublin Medical Journal for September 1835.—Ed.

ERECTILE TISSUE.) Thus an aneurism by anastomosis is made to increase by heat, by passion, or by excess of any description, and by the removal of these, or by the application of opposite influences, its growth may be checked, or its pulsation stopped. But when once formed, it remains for ever, unless removed by spontaneous ulceration, by adhesive inflammation of the cells, or by operation; for although, if the general circulation be depressed, that in the tumour will be less active also, yet the structure is there still unaltered and ready to receive the blood and to exhibit all its wonted phenomena whenever the requisite stimulus is applied.

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(W. H. Porter.)

ARTICULATA (*articulus*, a joint,) a primary division of the animal kingdom founded by Cuvier,* and characterized by him as follows: "Body jointed externally, corresponding to the divisions of the nervous system internally: a very small brain placed above the œsophagus gives off two filaments which extend along the abdomen and unite together from distance to distance by means of ganglions, which resemble as many small brains, from which nerves are given off. The muscular system is disposed on the inside of the rings or segments of the body so as to separate and approximate these segments; when there are articulated members, the muscles of these parts are also placed within the hard parts. The divisibility of the body, and the power which the fragments possess of retaining a kind of independent

* This division was virtually established by Cuvier in his earliest work, the "Tableau Elémentaire de l'Histoire Naturelle des Animaux," although it was not defined with that clearness, nor its characters so fully developed as in the Règne Animal. In the "Tableau Elémentaire" the second section of 'white-blooded animals,' including the *Insecta* and part of the *Vermes* of Linnæus, corresponds precisely with Lamarck's division of invertebrate animals, which he first denominated 'Articulosa.' (Hist. Nat. des Animaux sans Vertebr. tom. i. p. 454.)

vitality corresponds to the distribution of the nervous system into as many centres as there are corporeal segments."* With respect to the agreement between the number of segments of the body and the ganglions of the nervous system, it must be observed that in the higher crustaceans, arachnidans, and insects, the ganglions, though originally as numerous as the segments, subsequently become concentrated by progressive development into masses which are fewer in number, and that also in some of the lowest annelidans, as the leech-tribe, the external segments are more numerous than the internal ganglions.

In many of the molluscous class two nervous cords proceed backwards from the supraœsophageal ganglion or brain, and are afterwards brought into communication by ganglionic masses on the ventral aspect of the body; but in the Articulata the uniting ganglions are always confined to the mesial line of the body, are perfectly symmetrical in their arrangement, and are accompanied by a symmetrical or bilateral form of the whole body. It is this *homogangliate* disposition of the nervous system which essentially distinguishes the Articulate from the Molluscous and other divisions of the Animal Kingdom, and it is an infallible guide to the true affinities of the classes possessing it. The *Cirripeda* present a striking example of this fact: these animals, on account of their inarticulate body enveloped in a fleshy mantle and protected by a multivalve shell, were for a long time classed with the mollusca: but the views of those naturalists who considered that they had closer relations to the *Articulata*, although that opinion was founded on a knowledge of their nervous system only, has since been corroborated by every additional fact which has been discovered respecting them. Latreille, in his "Familles Naturelles du Règne Animal," first placed the cirripeds in the Articulate series, but being guided by their adult organization, and supposing that they were deficient in visual organs, and underwent no metamorphosis, he joined them with the annelidans, to form a division of Articulate animals, "*Elminthoida*," distinct from the "*Condylopeda*," which include the insects, arachnidans, and crustaceans, or the Articulata *with jointed feet*. The later researches of Mr. I. V. Thompson and Dr. Burmeister† have proved that in the immature state the Cirripeds undergo repeated metamorphoses or moults; that they move freely in the water by means of setiferous articulated members, and during this period guide their wanderings by the aid of distinctly developed, though simple eyes.

Besides the cirripeds the higher organized infusoria and intestinal worms have been proposed by some naturalists to be added to the articulate division of Animals: but as they are neither articulated nor possess articulate members, and as their nervous cords are simple and not brought into communication by a regular series of ganglions, we prefer to leave the Rotifera and Cœlelmintha with the Entozoa and Echinodermata, as a separate and higher subdivision of Cuvier's Radiata, and thus preserve the Articulata as a distinct and well defined subkingdom, characterized by a dispersion of the nervous system in a series of ganglions, symmetrically arranged and brought into communication by a double nervous cord; by an articulate or jointed structure of the body or its appendages, by the lateral position and horizontal movements of the jaws, when these are present, and by the presence of distinct respiratory organs. The subdivisions of this subkingdom are not founded on the modifications of any single system, but principally rest on the conditions of the sanguiferous and respiratory organs, in connexion with exterior form, modes of locomotion and generation.

I. The *Cirripeds, (cirripedia, cirripeda, cirrhopoda)*; oceanic animals called barnacles and acorn shells: they are characterized by their fixed condition, being either sessile, or attached to foreign bodies by means of a peduncle; their generation is, consequently, hermaphrodite, without the intercourse of separate individuals, but the male and female organs are distinctly developed in each animal. The blood is colourless and is propelled by a dorsal vasiform heart, but the venous system is diffused. The branchiæ are internal. The cirripeds undergo metamorphoses, but are ultimately inclosed in an inarticulate defensive covering of shelly pieces varying in number, form, and size.

II. The *Annelidans, (Annelida, red-blooded worms,)* are always locomotive; and, consequently, although hermaphrodites, they enjoy the intercourse of the sexes, and reciprocally fecundate each other. Their blood, which is generally red, like that of the vertebrate animals, circulates in a closed system of arteries and veins, which sometimes has appended to it several well-marked propulsive cavities or hearts; they respire by means of organs sometimes developed externally, sometimes remaining on the surface of the integument, or lodged in its interior. Their body, which is of an elongated form, and covered with a soft skin, is always divided into numerous transverse segments, of which the first, called the head, scarcely differs from the others, except by the presence of the mouth and of the principal organs of the senses. Many possess branchiæ, arranged the whole length of the body, or situated at the middle; others, which for the most part inhabit tubes, have the branchiæ collected at the anterior part of the body; in others, again, the respiratory organs are in the form of internal air sacs. The annelidans never possess articulated limbs, but many have, instead thereof, stiff bristles, or hooks, frequently inclosed in tubular prolongations of the integument.

The other *articulate classes*, viz., *insects, arachnidans*, and *crustaceans*, differ from the preceding classes in the possession of articulated limbs, terminated by claws; and in

* See his celebrated memoir, "Sur un nouveau rapprochement à etablir entre les classes qui composent le règne animal." "*Annales du Muséum d'Histoire Naturelle*, 4to, tom. xix. p. 73.

† Beiträge zur Naturgeschichte der Rankenfuesser, 4to. Berlin, 1834.

connexion with the superior powers of locomotion afforded by these appendages, the sexes are separate, and the organs of vision are well developed, and often highly complicated. With the exception of some genera, as the myriapoda, in which the body is divided into a number of nearly equal segments, and of the *arachnida* and many *crustacea*, in which the head and thorax are blended together, the body of the condylopes of Latreille is divided into three principal parts, viz., the *head*, which bears the antennæ, the eyes, and the mouth; the *thorax*, which supports the feet and the wings, when the latter are present; and the *abdomen*, which contains the principal viscera.

These segments present different degrees of hardness in the different classes of condylopes, being most flexible in the arachnidans, firmer in the insects, and calcareous in most of the crustaceans. The origin of the *insections* or articulations of the body which form so marked an external character of these animals, is as follows:—

The integument is composed of two layers or pellicles, viz., the epidermis and the corium, and is originally of equable consistence, and presents an uninterrupted continuity, save by some slight transverse superficial wrinkles. The epidermis subsequently becomes solidified, in arachnidans and insects, by the superaddition of a peculiar substance termed *chitine*, and in crustaceans by a calcareous deposition, so as to be divided into bands or rings. As the external development proceeds, these epidermic pieces are detached posteriorly from the inferior pellicle, or corium; and the intervals of the segments remaining membranous, and preserving their flexibility, yield readily to the various movements and inflections of the body.

The IIId class of articulate animals or *Insects (Insecta)*, are either myriapod or hexapod. Most of the latter are furnished with wings, which they acquire at a certain age, after undergoing metamorphoses varying in kind and degree. In every state they respire by tracheæ, or elastic vessels which receive the air by stigmata, situated along the sides of the body. A dorsal vessel propels the circulating fluid, which is afterwards diffused throughout the cellular tissue of the body. They have conglomerate or compound eyes, and antennæ.

IV. The *Arachnidans (Arachnida*, Spiders, Scorpions, &c.), are octopod and apterous; they have no antennæ, and have simple eyes. Their circulation is effected by a dorsal vasiform heart which transmits arterial branches, and receives the returning blood from veins. Their organs of respiration vary, some possessing true pulmonary sacs which open upon the sides of the abdomen, others receiving the air by tracheæ, like insects. In both cases, however, the air is respired by lateral orifices or true stigmata.

V. The *Crustaceans (Crustacea)* have never less than ten feet; they have two compound eyes, and also antennæ, which are generally four in number; their blood, which is white, is circulated by means of a muscular ventricle situated on the back. They respire by means of gills, and have no stigmata, or spiracles on the surface of the skin.

In the Articulate sub-kingdom, as in the vertebrate, there may be traced one general plan of structure pervading all the classes, but with such variations in it as are, in each case, demanded by the particular exigencies of the individual to which it is applied; but these variations are of such a nature, that a gradation of complexity or perfection may be followed through all the organic systems. With regard to locomotion, we commence with a class (the Cirripeds) as fixed and immoveable as the polypes and sponges of the Acrite sub-kingdom; and afterwards trace a series of forms adapted first to slow and tortuous reptation; next to swifter progression, as creeping, running, or leaping; and, lastly, to a rapid flight through aerial space.

Generation, in like manner, is effected, in the lowest class, without the intercourse of separate individuals; afterwards by the reciprocal impregnation of co-equal hermaphrodites, and, lastly, as in the vertebrate division, by individuals of distinct sexes.

The perfection of the nervous system results from the approximation of many separate ganglions into fewer masses of nervous matter. The organs of the senses also augment in number and complexity.

The Articulata present, in the organs of the vital functions, as strongly marked differences as are met with in the vertebrate animals. With respect to the sanguiferous system, a gradation may be traced from a circulation in closed vessels to a diffused condition of the nutritious fluid; and a corresponding passage from the articulata which respire by means of circumscribed branchiæ, to those in which indefinitely ramified tracheæ carry the air to all the parts of the body. The amount of respiration thus produced occasions the same effects here, as in the Vertebrate sub-kingdom, and the Insects thus constitute, as it were, the Birds of the Articulate division of animals.

(Richard Owen.)

ARTICULATION *(in anatomy)*, synonymous with *joint*. (Gr. αρθρον. Lat. *articulus*, *arthrosis*, *junctura*. Fr. *articulation*. Germ. *Articulation*, *Gelenk*. Ital. *articolo)*.

The power of motion, to an extent however limited, seems to be inseparable from our idea of an animal, and in looking through the animal series we find none which do not appear to be endowed with this power whether for the purpose of progression, or simply of altering the position or condition of some part of their bodies with respect to the others. The organic structure which is the immediate agent in this motive power (the muscular fibre), is one and the same throughout the whole chain of animals, variously modified according to the degree and force of the motions necessary for the particular individual. The mechanism by which this structure acts upon the different parts of the body varies considerably, and increases in complexity as the forms of the animals themselves become more complex. In the lowest grade of animals the structure is so soft and pliant that nothing more is required to produce motion than this contractile tissue, which acts in obedience to certain stimuli. But when hard parts are superadded to the structure of the animal, we then find a peculiar mechanism to allow of the motion of these hard parts on each other without the risk of injury. It is obvious that such motion could not take place were these hard parts united in one piece. Hence we find that they are subdivided into segments, and these segments are joined to each other through the medium of some structure more flexible than that of the segments themselves, or by an apparatus of such a construction as to admit of the motion of one segment upon the other. It is to these joinings of different segments of an animal body that the term *articulations* or joints has been applied.

An articulation may, therefore, be defined to be the union of any two segments of an animal body through the intervention of a structure or structures different from both.

The most perfect and elaborate forms of articulations are those which are seen in animals that possess a fully developed internal bony skeleton, and in none may they be studied with more advantage than in man. We propose to treat of the forms and structure of the articulations in man, and at the same time to inquire what modes of mechanism are employed for analogous purposes in the lower classes. In the human subject and in the vertebrated animals generally, we shall, indeed, have particular occasion to admire the articulations, as mirabiles commissuras, et ad stabilitatem aptas, et ad artus finiendos accommodatas, et ad motum et ad omnem corporis actionem.*

It will be observed that the definition here given of articulation is of the most comprehensive nature. In most instances, in man, two parts articulated together are joined by their solid portions, which are never in immediate apposition with each other, but have some elastic structure interposed which may or may not form a bond of union; and it is obvious that the fact of the intervening substance being, or not being also a bond of union will greatly influence the extent of motion of which the joint is capable. Before inquiring into the variety of forms of joints, we shall first examine briefly the various structures which enter into their composition, and which essentially contribute to the perfection of their mechanism.

These parts may be enumerated as follows, and we propose to observe the same order in treating of them: — 1. Bone. 2. Cartilage. 3. Fibro-cartilage. 4. Ligament. 5. Synovial membrane.

1. *Bone.* — The osseous or an analogous structure constitutes the fundamental portion of an articulation in all the vertebrated animals, in the mollusca, and in some of the articulated classes. In the human subject and all vertebrated animals we find that certain parts of the bones have surfaces marked upon them in correspondence with similar surfaces on others with which they are connected, or that, as in the long bones, the extremities are expanded or enlarged, and present surfaces which are adapted to similar surfaces on contiguous bones. In this way are formed the articular portions of the bones, and we observe that these portions present considerable varieties in their characters according to the nature of the articulation which they contribute to form. In fact, in examining these articular portions of the bones we cannot fail to notice the diversity of their form, so that some are adapted to each other in such a manner as evidently to favour motion, and others are so framed as to limit and restrict it. The articular surfaces in dry bones are generally characterised by a peculiar smoothness, indicative of the existence on them of a cartilaginous incrustation in the recent condition. The expansion of the extremities of the long bones on which the articular surfaces are formed is to be attributed to the accumulation there of a considerable quantity of the reticular texture, covered by a thin lamina of compact tissue, whereby a large surface is obtained without the inconvenient increase of weight which would necessarily result did that portion of the bone contain compact tissue to any extent. In the neighbourhood of the articular portions of the bones we find certain eminences, depressions, or roughnesses, which indicate the points of attachment of those bonds of union by which the joints are secured and strengthened. In general it may be observed that the long bones are articulated with each other by joints which possess a considerable extent of motion; the flat bones, again, have articulations very limited in their mobility, and this is likewise the case with the irregular bones.

2. *Cartilage.*—Pure cartilage enters into the composition of almost all joints, but more particularly of those which are very moveable, and indeed the chief purpose for which it is employed in the economy of adult animals is as an important and valuable element in these moveable joints. *Articular* cartilage, therefore, constitutes a primary subdivision of this texture by systematic writers. Its hardness, its elasticity, and the limited degree of organization which it possesses, peculiarly adapt it for the purposes to which it is applied in the mechanism of the articulations.

Although cartilage is chiefly employed in those joints which possess considerable mobility, it nevertheless also exists in joints which are limited in their motions, and as it possesses peculiar characters according as it belongs to one or other of these classes of articulations, we may very conveniently subdivide it into— *a*, cartilage of moveable articulations, or articular cartilage properly so called, or diarthrodial cartilage; *b*, cartilage of articulations very limited in their motions, or cartilage of sutures, or synarthrodial cartilage. Under these heads we propose to treat of articular cartilage.

* Cicer. de Nat. Deor. l. ii. c. 35.

a. Diarthrodial cartilage. — The general characters of this class of articular cartilage may be best examined on the articulating extremities of the long bones. Here we observe it moulded exactly to the forms of those surfaces, insomuch that, after a little maceration, the cartilage may, by careful dissection, be removed from the bone, to which it adheres with great firmness, and will be found to exhibit an exact mould of the articular extremity; hence these cartilages have been called "*cartilages of incrustation.*" This cartilage is perfectly distinct at the early periods of life from the temporary cartilage which forms the nidus of the future bone, and cannot be regarded as a portion of that cartilage left unossified; this may easily be seen by examining a vertical section of a femur or tibia at this period; and the peculiar arrangement of the fibres of the articular cartilage, hereafter to be noticed, constitutes an additional proof that it is completely distinct from that which is afterwards transformed into bone.

The physical properties and general characters of this form of cartilage do not differ from those of the others; it possesses the same pearly whiteness—the same apparent homogeneousness of structure—the same elasticity—the same absence of vessels carrying red blood. It is not covered by a perichondrium; the surface towards the joint is peculiarly smooth and glistening, and is generally supposed to owe these properties to its being lined by a layer of the synovial sac of the joint; this point, however, has been controverted, as we shall notice in a subsequent part of the article. The first and the most complete investigation of the true anatomical construction of articular cartilage was that announced by Dr. William Hunter so long ago as 1743.* His paper still deserves the most attentive perusal, not only for the actual information it affords on its professed subject, but as a specimen of the careful and original method of observation pursued by its distinguished author. To examine the structure of articular cartilages, it is necessary to subject them to boiling or a long-continued maceration.†

"When an articulating cartilage is well prepared," says Dr. Hunter, "it feels soft, yields to the touch, but restores itself to its former equality of surface when the pressure is taken off. This surface, when viewed through a glass, appears like a piece of velvet. If we endeavour to peel the cartilage off in lamellæ, we find it impracticable, but if we use a certain degree of force, it separates from the bone in small parcels, and we never find the edge of the remaining part oblique, but always perpendicular to the subjacent surface of the bone. If we view this edge through a glass, it appears like the edge of velvet, a mass of short and nearly parallel fibres rising from the bone, and terminating at the external surface of the cartilage: and the bone itself is planned out into small circular dimples where the little bundles of the cartilaginous fibres were fixed. Thus we may compare the texture of a cartilage to the pile of velvet, its fibres rising up from the bone, as the silky threads of that rise from the woven cloth or basis. In both substances the short threads sink, and bend in waves upon being compressed, but by the power of elasticity recover their perpendicular bearing as soon as they are no longer subjected to a compressing force. If another comparison was necessary, we might instance the flower of any corymbiferous plant, where the *flosculi* and *stamina* represent the little bundles of cartilaginous fibres, and the calyx, upon which they are planted, bears analogy to the bone."*

The total absence of vessels capable of carrying red blood in articular cartilage is proved by the failure of even the minutest injections to pass into the cartilage, and a further confirmation of this opinion is derived from the fact that madder taken into the system of a young animal does not stain them. The attempts of anatomists to trace lymphatics and nerves into this structure have been equally unavailing.

The design of articular cartilages, as means to break the violence of shocks, is well illustrated by comparing the different arrangement of the cartilaginous incrustation on convex articular surfaces from that on concave. In the former, we observe the layer of cartilage to be very thin at the circumference of the articular surface, its thickest portion being in the centre, while the opposite arrangement obtains on concave surfaces: there the thinnest portion of the cartilage is in the centre, and the layer increases in thickness as it approaches the circumference.

"The articulating cartilages are most happily contrived to all purposes of motion in those parts. By their uniform surface they move upon one another with ease: by their soft, smooth, and slippery surface mutual abrasion is prevented: by their flexibility, the contiguous surfaces are constantly adapted to each other, and the friction diffused equally over the whole: by their elasticity, the violence of any shock, which may happen in running, jumping, &c. is broken and gradually spent; which must have been extremely pernicious, if the hard surfaces of bones had been immediately contiguous. As the course of the cartilaginous fibres appears calculated chiefly for this last advantage, to illustrate it, we need only reflect on the soft undulatory motion of coaches, which mechanics want to procure by springs, or upon the difference betwixt riding a chamber-horse and a real one."†

* Of the Structure and Diseases of Articular Cartilage, Phil. Trans. vol. xlii.

† The articular cartilage on the patella may be selected as very favourable for this purpose. See the plate annexed to W. Hunter's paper.

* Loc. cit. p. 516.

† Hunter, in loco citato. Hunter's account of articular cartilage is completely confirmed by M. De Lâsone in a paper in the Mém. de l'Academie Royale des Sciences, An 1752. He describes the cartilage as "une multitude des petits filets adossés et liés les uns aux autres tous perpendiculaires au plan de l'os, en un mot parfaitement semblables par leur structure, ou par leur position à la substance emaillée des dents, laquelle n'est composée, comme on sait, que de filets osseux, posés perpendiculairement sur le corps de la dent: la comparaison est des plus exactes."

b. Synarthrodial cartilage.—The cartilages of synarthrodial articulations are destined in some degree to act as bonds of union, as well as means of separation and for the prevention of the effects of concussion. They are simply cartilaginous laminæ interposed between the osseous articular surfaces, very adherent to both, and adherent likewise by their margins to the periosteum or ligamentous expansions which may pass from one bone to another. We find instances of these cartilages in the sacro-iliac symphysis, or *synchondrosis*, as it has been called from the junction of the bones by cartilages;* also in the sutures, where there are very thin cartilaginous laminæ interposed between the osseous margins. These laminæ will be found to be triangular in their section, the thin edge or apex being internal, which, as Meckel observes, may in some degree account for the earlier obliteration of the sutures on the internal than on the external surface of the cranium. These cartilages of sutures are not strictly permanent; they disappear with age: and according to Beclard, hold the midway, as to frequency of ossification, between permanent and temporary cartilages.†

The cartilages of the ribs perform in some degree the office of articular cartilage; they are situated between two osseous surfaces; they form bonds of union, and their elasticity is eminently essential to the full performance of the movements of the thorax.

In fishes most of the moveable articulations are provided with elastic cartilages, which serve the double purpose of forming bonds of union as well as of permitting motion by their elasticity.

3. *Fibro-cartilage.*—This remarkable structure, called by the older anatomists *ligamentous cartilage* or *cartilaginiform ligament*, is made much use of in the articulations; and it is well adapted for a means of union, by reason of its great strength, which it owes to its ligamentous part, and of its elasticity, for which it is indebted to its cartilaginous portion. We find fibro-cartilage to be connected with the joints under three forms:

a. In the form of laminæ, free on both surfaces to a greater or less extent, and lined to the same extent by the synovial membrane reflected upon them.‡ These are the interarticular cartilages or *menisci* of authors. They are found in the temporo-maxillary, sterno-clavicular, and tibio-femoral articulations, sometimes in the acromio-clavicular, between the bodies of the cervical vertebræ in birds, and in general in those joints where there is constant and extensive motion, and consequently where the articular surfaces are exposed to considerable friction. The principal use of these fibro-cartilaginous laminæ must unquestionably be to guard against any bad consequences likely to arise from this continued friction; this is particularly obvious in the sterno-clavicular articulation. To increase the depth of an articular excavation is another object, as appears from the semilunar cartilages of the knee-joint; and moreover, in conjunction with the attainment of these two objects, to ensure in all the motions of the joint a perfect adaptation of the articular surfaces to one another, as will appear obvious to any one who carefully considers the construction of the temporo-maxillary or even of the knee-joint.

It will be observed, that I do not include in the class of interarticular fibro-cartilages, the lamina which is commonly known by the name of the *triangular cartilage* of the wrist joint, as is done by all the systematic writers I have looked into; for, first, it does not appear to me to be fibro-cartilaginous in its structure; it is purely cartilaginous; and, secondly, it is not interarticular, in the sense in which we here use that term, viz., as lying between two articular surfaces. This lamina seems to be merely an extension of the cartilaginous incrustation of the inferior extremity of the radius, which completes the articular surface for the reception of the first row of carpal bones. The scaphoides and lunare are provided for by the radius; but as the ulna could not be brought into the composition of the wrist-joint without interfering with the motions of the inferior radio-ulnar articulation, a structure such as the triangular cartilage, was necessary—one which would present a sufficient opposing surface to the articular portion of the os cuneiforme, and which would not impede or obstruct the necessary motions of the joint between the radius and ulna.

In the cases of the temporo-maxillary and sterno-clavicular articulations, these fibro-cartilages form, in general, complete septa between two portions of the joint: so that there are then two synovial sacs; but sometimes there is a perforation in the centre of the fibro-cartilage.

b. The second class of articular fibro-cartilages consists of those which Meckel designates *fibro-cartilages of circumference*, or *cylindrical fibro-cartilages.* They form fibro-cartilaginous brims to certain articular excavations; they are triangular in their section, attached by their basis to the osseous margin of the articular cavity, and free at their apices, lined by synovial membrane on the whole of one side, and a great part of the other. They are to be found only in two joints, namely, on the margin of the acetabulum in the hip-joint, and on the edge of the glenoid cavity in the articulation of the shoulder; in the former, this fibro-cartilage is much larger and stronger, and is evidently

* No one can have failed to notice the peculiar yellow appearance of the cartilage in the sacro-iliac articulation. Does that arise from an admixture of the yellow elastic tissue with the pure cartilage, by which the elasticity of the latter is increased?

† It is doubted by some whether these cartilaginous laminæ can be admitted into the class of articular cartilages; they being regarded as forming a nidus for the extension of the flat cranial bones, and the sutures being supposed to be useful only for this purpose, viz. to admit of the growth of these bones at their margins in a manner analogous to that of long bones at their extremities. See Soemmerring de Corp. Hum. Fab. t. i. p. 212, and Gibson on the use of sutures in the skulls of animals, Manchester Memoirs, 2d series, vol. i.

‡ This point, however, is liable to the same objections as that of the continuity of the synovial membrane over diarthrodial articular cartilages, which will be considered in a subsequent part of the article.

intended to obviate the ill consequenees which must have resulted from the violent applieation of the neck of the femur against the bony margin of the acetabulum: for, where the margin of that cavity is ligamentous, viz., at the notch on its inner side, this fibro-cartilage does not exist.

c. The most remarkable and beautiful variety of this structure belongs to the third elass. It consists of fibro-eartilaginous laminæ, generally of considerable thickness, which intervene between two bones and adhere intimately to each. Examples of it are to be found between the bodies of the vertebræ, (intervertebral substance)—between the pieces of the sacrum in early life—between the sacrum and coccyx, and between the pieces of the latter—also, between the ossa pubis at the joint called the symphysis pubis. In this class of fibro-cartilages too, we may place that which is situated between the scaphoid and lunar bones in the carpus.

It is evident that these fibro-cartilages are useful, not only as very powerful bonds of union, but also as elastic cushions placed between the bones to prevent the concussion which must necessarily result, did the unyielding bony surfaces come together with any degree of force. No where is this so beautifully exhibited as in that chain of bones which forms the spinal column in the mammiferous vertebrata, the strength and flexibility of which result from the fibro-cartilaginous discs, which, placed between the bodies of the vertebræ, are commonly called *intervertebral cartilages.*

As to the structure of articular fibro-cartilage, we can distinctly observe, without any process of dissection, that it is compounded of fibrous tissue as well as of cartilage. As these fibro-cartilages generally assume more or less of the circular form, we find that the fibrous tissue is most abundant towards the circumference, and that the cartilage is most manifest at the centre. In the intervertebral substance, the fibrous tissue is arranged in concentric laminæ, placed vertically behind one another. Each lamina is composed of a series of interlacing fibres, which have intervals between them; these intervals, as well as those between the laminæ, are filled by cartilaginous tissue; towards the centre the fibrous laminæ diminish in number, the intervals become large, and at length the fibrous tissue disappears in toto; hence the gradually diminishing density towards the centre, which characterises the intervertebral substance. In fishes, there is such a diminution of density, that the central part is fluid, but here the surfaces of the vertebræ are excavated, not plane as in the mammiferous vertebrata, and the character of the articulation is thereby materially altered. The incompressible central fluid forms a ball, round which the cup-like excavations of the vertebræ play, while the fibro-cartilage at the circumference is made available in the lateral motions of the spine.

Of the three varieties of fibro-cartilage above enumerated, the menisci possess the most cartilage in their structure, and the circumferential fibro-eartilages the greatest quantity of fibrous tissue.

It may be questioned whether that peculiar structure which intervenes between the base of the skull and the condyle of the lower jaw in the whalebone whale, (*balæna mysticetus*) belongs to the class of fibro-cartilages, although it seems to bear a nearer resemblanee to that than to any of the other structures employed in the composition of joints. The following is Sir Everard Home's description of it.* "Between the condyles of the lower jaw and the basis of the skull is interposed a thick substance, made up of a network of ligamentous fibres, the interstices of which are filled with oil, so that the parts move readily on each other. The condyles have neither a smooth surface nor a cartilaginous covering, but are firmly attached to the intermediate substance, which in this animal is a substitute for the double joint met with in the quadruped, and is certainly a substitute of the most simple kind."

4. *Ligament.*—The term *ligament*, as it is used by systematic writers on descriptive anatomy, is by no means confined to portions of the "fibrous system" of Bichat, although all the articular ligaments (properly so called) belong to that system. Weitbrecht comprehends under this term all fibrous structures in and about joints, including the fibrous sheaths of tendons, and also all membranous folds, which are in any way concerned in maintaining soft parts or viscera *in proprio situ*. I apprehend, however, that a better definition of *articular ligament* could not be given than the following, which is that of Weitbrecht, the words printed in italics being added,—"Ligamentum est particula corporis, *plerumque* albicans, *interdum flava,* ex fibris flexilibus, *interdum* elasticis, plerumque parallele concretis, in substantiam tenacem fibrosam, ruptioni fortiter resistentem, et solidam compacta, eum in finem creata ut duæ pluresve partes quæ alias divulsæ per se subsisterent, adunentur atque in situ respectivo determinentur."† Most of the articular ligaments are employed to unite the bones which compose a joint; they also will be found uniting some of the interarticular cartilages within joints, or passing from one part of a bone to another (forming the "mixed" class of ligaments of Beclard); and such is the vagueness with which names are applied in descriptive anatomy, that folds of the synovial membrane often receive this appellation without the least title to it.

Artieular ligaments are divisible as regards their forms into two species, the capsular and the funicular or faseicular.‡

Capsular ligaments are generally cylindrical in shape, or rather barrel-shaped, being wider in the centre than at the extremes. Eaeh extremity envelopes one of the bones that enters into the formation of the joint, so that the articular cavity is completely surrounded by and enclosed within the ligamentous capsule. Liga-

* Comp. Anat. vol. i. p. 83.
† Syndesmologia, § 5.
‡ Beclard, Anat. Gen.

ments of this kind are composed of fibres which are closely interwoven with each other, and they sometimes receive accessions from bundles of ligamentous fibres coming from neighbouring bony prominences (these fibres being generally called *accessory ligaments.)* Capsular ligaments are not calculated to restrict the extent or direction of motion between the bones which they surround, and we consequently find them only in that kind of joint which admits of motion in all directions, viz. the *enarthrosis* or *ball-and-socket* joint, of which the only examples in the human subject are to be met with in the hip and shoulder. The internal or articular surface of capsular ligaments is to a great extent lined by one lamina of the synovial membrane, which is reflected upon it from the articular portion of the most moveable of the bones which form the joint.

Funicular ligaments are found in the form of rounded cords or flattened bands: they exist generally on the exterior of joints, very rarely on the interior, and always externally to the sac of the synovial membrane. They pass from bone to bone, adherent sometimes to the synovial membrane of the articulation, sometimes to the intervening fibro-cartilage. In ginglymoid joints they are always placed on the sides, and are called *lateral* ligaments; sometimes they cross or decussate with each other, whence the appellation *crucial*, and sometimes a ligament of this class assumes a nearly circular course, and forms a greater or smaller portion of the circumference of a circle, the remainder of the round being completed by the bone into which the extremities of the ligament are fixed; a ring is in this way produced within which the head, or a special process of another bone, is enclosed, as is seen to be the case particularly with the head of the radius in the superior radio-ulnar articulation, and with the processus dentatus in the joint between the axis and atlas: the ligament in such instances is called *coronary*. When a ligament is concealed in the interior of a joint, although situated externally to the synovial sac, or, to speak more correctly, in the space between the articular surfaces, it is called an *internal* ligament, e. g. the ligamentum teres of the hip-joint, the mucous ligament of the knee, or the transverse ligament of the same articulation.

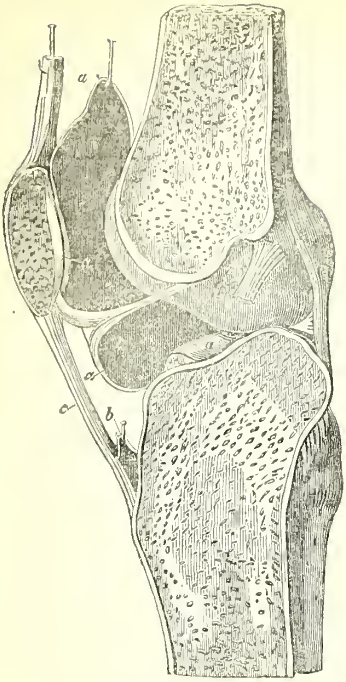
Elastic ligament.—Hitherto we have been examining ligamentous structure, one of whose most prominent characteristics is the want of elasticity; but we now come to a kind of ligament which forms a most valuable constituent in the mechanism of some joints, and is eminently distinguished for the great elasticity which it possesses. It differs from ordinary ligament by its yellow colour, (whence the French appellation *tissu jaune,)* as well as by its elasticity. We find it in the human subject most developed in the *ligamenta subflava* of the vertebræ. In joints, as elsewhere, this tissue is employed to restore to the position of quiescence, parts which have been previously acted upon by muscular contraction. John Hunter fully appreciated the value and utility of this structure in supplying the place of muscle, with less expense of exertion to the economy, and assigned it a place in the arrangement of his museum.* The thyro-hyoid and crico-thyroid ligaments in man are formed of this structure.

5. *Synovial membrane*.—The articular synovial membranes, (by the older anatomists called, and confounded with, the capsular ligaments,) like all others, possess in common with serous membranes the form of a sac shut in all points; they line the whole interior of the joints, and secrete from their internal surface a peculiar fluid, obviously destined for the lubrication of the articular surfaces. These membranes are remarkable for their great tenuity; they are transparent; in a state of inflammation, their vascularity, which is imperceptible during health, becomes very apparent by the general redness which the membrane assumes; and their internal or secreting surface is easily distinguished from the external, by contrasting the smooth and glistening appearance of the former with the roughness which the latter receives from the cellular tissue and ligamentous fibres which adhere to it. The internal surface of the membrane is sometimes thrown into folds with fringe-like margins, which project into its cavity or sac. These folds contain more or less of cellular tissue and a number of pellets of fat, which being supplied with vessels, the margin of the synovial fringe is sometimes tinged red. These folds are compared, and certainly with much justice, to the epiploic folds of the abdominal serous membranes, more especially to the appendices epiploicæ of the great intestine. Beclard supposes that these fringes are specially the seat of the synovial secretion, which being perspiratory likewise takes place, though less abundantly and manifestly, from the rest of the synovial surface. The best examples of these folds occur in the knee and hip-joints, in the former of which they have been absurdly called *alar ligaments*.

Some idea may be formed of the manner in which the synovial membrane is related to the other articular structures by examining the annexed figure, (*fig*. 111,) representing a vertical section of the knee-joint. The cut margin of the synovial membrane is indicated by *a*, which after lining the posterior surface of the patella and ligamentum patellæ, is reflected upon the condyles of the femur, whence it is carried in front of the crucial ligaments to line the articular surface of the head of the tibia, and from that is again reflected upwards, and is continuous with the portion lining the posterior cartilaginous surface of the patella. This description is founded on the opinion, which I believe to be correct, that the analogy between serous and synovial membranes is accurate, in so far as their possessing in common the form of shut sacs is concerned. On this subject, how-

* Vide Home's Lect. on Comp. Anat. Lect. i. vol. i.

Fig. 111.



ever, anatomists are by no means likely ever to be unanimous, because of the difficulty or impossibility of tracing by the ordinary methods of dissection the synovial membrane over the articular cartilages. The continuity of this membrane over the cartilage was first distinctly announced and described by Dr. W. Hunter, in the paper to which we have already referred in the Philosophical Transactions: after him Soemmerring described it, and still later Bichat, who insisted more particularly on its analogy with serous membranes. Bichat's description has been followed by Meckel, Beclard, and most of the anatomists of modern times; but its accuracy has been called in question by Cruveilhier,* Gordon,† Magendie,‡ Blandin,§ and more recently by Gendrin|| and Velpeau.¶

The advocates for the continuity of the synovial membranes over the diarthrodial cartilages, found their opinion on the following facts:—1. Synovial membranes elsewhere, lining tendinous sheaths or bursæ mucosæ, are distinctly and obviously shut sacs. 2. We do not find cartilage to present the smooth and polished aspect exhibited by the articular surfaces, excepting where it is connected with synovial membrane, as it evidently is to at least a certain extent in the moveable articulations. 3. If by an oblique cut we raise a slice from an articular cartilage, and turn it back so as to rupture it at its base, we shall find it still retained in connexion with the rest of the cartilage by a thin pellicle, which seems to have all the characters of synovial membrane. A similar membrane may be seen by sawing a bone vertically down to the cartilage, and then breaking the cartilage by forcibly separating the segments. 4. Some observers state that they have seen the redness of inflammation affecting the synovial membranes prolonged over the cartilage,* but becoming gradually less marked towards the centre—(this, I must confess, I have never seen). 5. Bands of adhesion are also said to have been met with in some cases of chronic inflammation of the synovial membrane, passing from the articular surfaces, as well as from other parts of the interior of the joint. 6. In that peculiar disease of the synovial membrane described by Brodie, the pulpy substance has been seen on the articular cartilages, as well as on the menisci.†

On the other hand, the opponents of this opinion deny: 1, that the membrane demonstrable by slicing the cartilage in the way above described, is any thing else than a very thin lamina of cartilage; 2, they say that by even the most successful injection the fluid cannot be made to pass beyond the margin of the cartilage; 3, they assert that inflammation always stops abruptly at the circumference of the cartilage; 4, and that if a synovial membrane did exist on the free surface of the cartilage, there would take place a continual exhalation of synovia from the articular surface, contrary to what was found to be the case in an experiment tried by Cruveilhier: synovia was freely exhaled from the membrane lining the ligaments, and after having been wiped off reappeared with rapidity; but not so over the articular cartilage, the surface of which became quite dry.‡

Cruveilhier, however, relates a case which in some degree invalidates his own conclusions; it was one in which fungous granulations sprang from the articular surfaces of the femur and tibia in the knee-joint, and by their adhesion produced anchylosis of the joint: this fact Cruveilhier § very candidly expresses his inability

* Observations sur les Cartilages diarthrodiaux. Arch. Gen. de Méd. tom. iv. p. 161.

† Gordon says, " the continuation of the synovial membranes over the surface of articulating cartilages is, I am convinced from a number of experiments, altogether an anatomical *refinement*."—System of Human Anatomy, p. 261.

‡ Compend. of Physiology, by Milligan, p. 450.

§ Additions à Bichat, par Beclard et Blandin, p. 345.

|| Hist. Anat. des Inflam. t. i. p. 60.

¶ Anat. Chir. ed. 2de, t. i. p. 176.

* I am uncertain whether the fourth case related by Sir B. Brodie in the last edition of his work on the joints, may not be regarded as affording an instance of this. In the account of the post-mortem examination it is said, " The synovial membrane was *everywhere* of a red colour, as if stained by the secretion," p. 15. Beclard, whose powers and accuracy of observation few will be disposed to question, speaks with the confidence of one who had seen this extension of the vessels over the cartilage.—Anat. Gen. p. 214.

† Vide the 17th, 18th, 19th, 21st, and 22d cases recorded in Sir B. Brodie's work.

‡ Cruveilhier, loc cit.

§ He confesses, " ma conviction n'est pas cependant pleine et entière."

to explain without admitting either the existence of the synovial membrane, or the organization* of the cartilages. Velpeau,† too, although he asserts that the synovial membrane "terminates at the circumference of the cartilages," furnishes us with an argument in opposition to his own views: namely, that no appreciable line of demarcation can be detected indicating where the synovial membrane ceases. "Viewed in this way," he says, "the synovial apparatus consists of surfaces, membranes, and glandular folds, between which there exists not the least interruption, and the use of which is to isolate the interior of the joint from the tissues which surround it."

It will appear then sufficiently evident that the weight of argument preponderates in favour of the doctrine that the synovial membranes line the articular surface of the cartilages, and that maintains their analogy with the serous membranes, an analogy which receives the strongest support from the physical properties of the synovial membrane, from its obvious functions during health, and from the diseases with which it is affected; and I apprehend, that nothing tends more fully to establish identity or similarity in the nature of two membranes, than the fact of a close resemblance between their morbid conditions. We may add, what was long ago remarked by W. Hunter, that this question as to the continuity of the synovial membrane on the cartilages is very similar to that as to the continuity of the conjunctiva over the cornea of the eye; the affirmation of which latter question, Gordon considers equally an *anatomical refinement* as that of the former.

Velpeau ‡ ascribes much importance to the dense and fine cellular tissue which is subjacent to the synovial membrane and is analogous to the subserous cellular tissue elsewhere. This would appear to be the seat of the vessels which in a state of inflammation give rise to the red colour of the synovial membrane. He particularly alludes to it as affording a clue by which the formation of loose cartilaginous bodies in joints can be explained; these he supposes to originate in sanguineous effusions into this tissue, which subsequently become indurated and cartilaginous, and push the synovial membrane before them into the cavity of the joint. It will be remembered by many readers that this opinion is very similar to that of John Hunter regarding the origin of these bodies. §

Allusion has already been made to the fatty bodies which are found in connexion with most of the joints, and in general lying behind the synovial fringes formerly described. These fatty pellets were supposed by Clopton Havers* to be the agents of the synovial secretion, and, in consequence, have obtained much celebrity under the title of *Haversian glands*.† The opinion of Havers and his followers as to their glandular nature was successfully combated by Bichat, who proved that they were merely composed of adipose substance, and in no way concerned in the function of synovial secretion: for 1st, the secretion of synovia takes place where no such bodies exist, as in almost all the bursæ mucosæ, and tendinous sheaths; aud 2d, these bodies have no trace of glandular structure, nor are they provided with any thing resembling an excretory duct; whilst, on the other hand, they possess all the properties of fat.

The synovial sac is lubricated by the synovia, also called *unguen articulare*, *axungia articularis*. How is this secreted? We believe it to be a perspiratory secretion precisely similar to that of the serum from serous membranes. Its formation cannot be imputed to a combination of the serosity of the blood with the fat, nor to the transudation of the marrow through the extremities of the bones, nor, with Desault, to a sweating from all the parts which enter into the composition of the articulation, inasmuch as the chemical analysis of synovia proves that it is essentially different from any oily fluid, and does not contain a trace either of elaine and stearine.

In addition to the structures already named as entering intrinsically into the formation of joints, we find that the tendons and muscles, which lie in the immediate vicinity of or which surround the joints, contribute much to their strength and security. In joints of the hinge kind we generally see the anterior and posterior parts protected more or less by the tendons of muscles, and even by muscles themselves passing from one segment of a limb to another, and here it frequently happens that the tendon is bound down on the bones which form the member, by a fibrous expansion of great strength, lined by a synovial membrane of the same characters as the articular, but adapted in its form to the osseo-fibrous canal in which the tendon is placed, e.g. the tendons of the fingers. The protection and strength afforded by muscles is particularly evinced in the case of the shoulder-joint, where the capsular ligament is closely embraced by four muscles, whose tendons become identified with the fibrous capsule as they go to be inserted into the bone. A muscular capsule, as it were, is thus provided for this joint, by which the bones are maintained much more firmly and powerfully in apposition than were they kept together by an uncontractile ligamentous capsule alone; hence the elongation of the arm which ap-

* This is a bad word; we cannot deny the organization of cartilages, however we may deny that they are supplied with red blood. It has been said, I know not with what authenticity, that cartilages have become yellow in jaundice.

† Loc. cit. pp. 172 and 174. He expresses his opinion much more decidedly in the art. ARTICULATIONS, MALADIES DES. Dict. de Med.

‡ Loc. cit. v. i. p. 173.

§ See Home's Paper, in Trans. of a Soc. for the improvement of Med. and Chirurg. Knowledge, v. i. 1793.

* Osteologia Nova: Lond. 1691.

† Weitbrecht called these fatty bodies, "Adiposo-glandulosæ;" and Cowper, "mucilaginous glands." See them figured in Monro's work on the Bursæ, Tab. viii.

pears as a consequence of paralysis, and hence also the greater liability to luxation which exists in a debilitated state of the system. Articular or capsular muscles thus placed, have also the effect, as it is said, of preventing the pinching of the capsule or synovial membrane between the articular extremities of the bones in the different motions of the joint.

The joints are very generally copiously supplied with blood, and are remarkable for the arterial anastomoses which take place around them. The best examples of these are met with in each of the joints of the extremities. The parts supplied with blood are the synovial membranes, the ligaments, the fat, and the extremities of the bones; but the cartilages certainly do not receive vessels carrying red blood: I believe there is no fact in anatomy, more generally admitted or better determined than this. The vascular ramifications which proceed from these vessels may be seen, particularly in young subjects, advancing in the subsynovial cellular tissue, and forming a vascular net-work there, as far as the margin of the articular cartilage where they stop abruptly; this is what W. Hunter described under the name of *circulus articuli vasculosus*.

Of the forms and classification of the articulations.—It is not difficult, by passing in review the various motions which take place between any two segments of a limb, to form an idea, *à priori*, as to the kinds and shapes of the articulations by which these segments will be united; it is only necessary not to lose sight of the fact, that in the construction of a joint regard is had not to its mobility alone, but to its security, its durability, and the safety of the neighbouring parts. We may expect to find joints varying in the *degree* of motion, from the slightest perceptible quantity, to the freest that is compatible with the maintenance of the segments in their proper relation with each other, and also in *extent* of motion, from that which is so slight as to admit of almost no appreciable change in the position of the parts, to that which allows of the most ample variety of relation between the segments, consistent with the integrity of the articulation.

It will appear, then, that the most simple kind of articulation is that by which two parts are so united as that the slightest appreciable degree of motion only shall exist between them. This constitutes the first great division of joints —the *Synarthrosis* (συν, *cum*, and αρθρον, *articulus*)—where the parts are continuous, *i. e.* not separated from each other by an intervening synovial cavity. Some anatomists consider all synarthrodial joints to be immoveable; which, although not far from the truth, cannot be said to be strictly accurate. Had immobility been the object to be obtained, I imagine that that might have been more effectually accomplished by the fusion of the extremities of the segments together, as in anchylosis.

In the second class of joints, motion is enjoyed freely and fully: this class is designated by the term *Diarthrosis* (δια, *per*, and αρθρον): the segments are interrupted completely in their continuity; the extremities of the bones can only be said to be contiguous.

Synarthrosis.—The general characters of the articulations belonging to this class are, 1. that they are very limited in their motion, insomuch as to be considered by some as immoveable; 2. that their surfaces are continuous, *i. e.* without the intervention of a synovial cavity, but with that of some structure different from bone. The following varieties may be noticed among synarthrodial articulations.

a. Suture (Germ. *Nath* or *Naht. Commissura cranii*, Vesal.).—When the margins of two bones exhibit a series of processes and indentations (dovetailing) which are received and receive reciprocally, with a very thin cartilaginous lamina interposed, this is the ordinary kind of suture, *sutura vera*, of which three kinds are distinguished: *sutura dentata*, where the processes are long and dentiform, as in the interparietal suture of the human skull; *sutura serrata*, when the indentations and processes are small and fine like the teeth of a saw, as in the suture between the two portions of the frontal bone; *sutura limbosa*, when there is along with the dentated margins a degree of bevelling of one, so that one bone rests on the other, as in the occipito-parietal suture.

When two bones are in juxta-position by plane but rough surfaces, the articulation is likewise said to be by suture, and this is the false suture, *sutura notha*, of which there are two kinds: *sutura squamosa*, where the bevelled edge of one bone overlaps and rests upon the other, as in the temporo-parietal suture, and *harmonia* (αρω, *adapto*), where there is simple apposition: this last kind of articulation is met with, as Bichat* observes, wherever the mechanism of the parts is alone sufficient to maintain them in their proper situation, as may be seen in the union of most of the bones of the face.

It is in the articulation of the bones of the skull and face of animals, as has been already noticed, that we see the best examples of sutures. In the chelonian reptiles, as the tortoise, the bodies, laminæ, and spinous processes of the vertebræ are united by suture, and the same mode of articulation unites the elements of the sternum of the land-tortoise to each other.† The bones of the head of birds and fishes are united chiefly by the harmonie and squamous sutures. In the lateral parts of the heads of fishes, and in the opercula of their gills, as between the opercular and subopercular bones, there is a species of articulation, most resembling the squamous suture, but differing from it in admitting a considerable latitude of motion by which these bones can glide on one another.‡ To descend still lower in the scale, we may observe a mode of joining very similar to suture, between the tubercular and

* Anat. Gen. t. iii. p. 63.

† See Grant's Comp. Anat. p. 83, fig. 43.

‡ Cuvier, Leçons d'Anat. Comp t.. i. p. 125.

ambulacral plates which form the shell-like covering of the echinida.*

The sutures have the peculiarity of a considerable tendency to become obliterated by age, the intervening cartilage being ossified; it rarely happens that the sutures are all manifest in a human skull past fifty years of age, and sometimes the obliteration takes place at a much earlier period. The frontal suture is by no means permanent; it is not often found at puberty. In birds and fishes this tendency to the obliteration of the sutures is particularly manifest.

b. Schindylesis (σχινδυλησις, *fissio*, σχιζω, *diffindo*).—This form of articulation is where a thin plate of bone is received into a space or cleft formed by the separation of two laminæ of another, as is seen in the insertion of the azygos process of the sphenoid bone into the fissure on the superior margin of the vomer; and in the articulation of the lacrymal bone with the ascending process of the superior maxillary.

c. Gomphosis (γομφος, *clavus*. *Clavatio*, *conclavatio*).—When a bone is inserted into a cavity in another, as a nail is driven into a board, or as a tree is inserted into the earth by its roots, the articulation is by gomphosis. The only example we have of it in the human subject or in quadrupeds is in the insertion of the teeth into the alveoli. In the weapon of offence of the saw-fish we find also an example in the manner in which the strong osseous spines are inserted like teeth into its lateral edges. Cuvier mentions a variety of gomphosis, the only modification of the above: it is where a bony process grows from the bottom of the recipient cavity, and is inserted into a cavity in the base of the received bone or hard part. This is the mode of articulation of the nails with the ungueal phalanges in animals of the cat kind; the nail is received into an osseous sheath, from the bottom of which the body of the phalanx projects and fills up the cavity of the nail. A similar pivot grows from the bottom of the alveoli, into which the long canine teeth of the walrus are inserted.

d. Amphiarthrosis (αμφι, *utrinque*, αρθρον, *articulus*, *i. e.* a mixed form of articulation. *Articulatio dubia*, Bartholin. *Synarthrosis diarthrodica*).—This is a form of articulation where two plane or mutually adapted surfaces are held together by a cartilaginous or fibro-cartilaginous lamina of considerable thickness, as well as by external ligaments. In virtue of the elasticity of the interposed cartilaginous or fibro-cartilaginous lamina, the amphiarthrosis possesses a manifest, although certainly a very limited degree of motion, and hence most systematic writers class it with the diarthrodial articulations. To me it appears much more consistent to place it among the synarthrodial joints, for, 1. its anatomical characters agree precisely with those of synarthrosis; 2. the surfaces in amphiarthrosis being continuous, it would make an exception in diarthrosis were we to place it there; and, 3. its degree of motion is greater than that of suture, only because of the greater development of the interosseous substance. These points of similarity led some anatomists to call it *Diarthrosis synarthrodica*; for the reasons above stated, as well as because it has one point of resemblance to diarthrosis in its greater latitude of motiou, I propose the appellation *Synarthrosis diarthrodica.*

The examples of this form of joint in the human body are the articulation between the bodies of the vertebræ, that between the two ossa pubis at what is called the symphysis, and that between the ilium and sacrum. We may also, I think, place here the articulation of the ribs with the sternum by means of the costal cartilages.* The bodies of the vertebræ in most of the mammalia are articulated in the same way; so are they in fishes also; but in these last there is a peculiarity already referred to, which increases the degree of motion of which the joint is susceptible.† Like the sutures, the amphiarthrosis is liable to become obliterated by age, and from the same cause, namely, the ossification of the interosseous lamina. This is very common in the costo-sternal joints, less so in the interpubic, and still more rare in the inter-vertebral and sacro-iliac.

Diarthrosis.—Evident mobility is the distinguishing characteristic of this class of joints; the articular surfaces are *contiguous*, each covered by a lamina of cartilage (*diarthrodial cartilage*), having a synovial sac, and in some cases two synovial sacs interposed, which are separated by a meniscus. The integrity of the articulation is maintained by ligaments which pass from the one bone to the other. Their mechanism is much more complicated than that of synarthrodial joints, being intended not only for security, but also to give a certain direction to the motions of which they are the centre.

Before proceeding to the enumeration of the varieties of joints that come under this head, it will not be amiss to describe briefly the various motions which may take place between any two segments of a limb, and which it is the object of these joints to admit of. It is obvious that the most simple kind of motion which can exist between two plane or contiguous surfaces, is that of *gliding*: one surface glides over the other, limited by the ligaments which extend between the bones. This motion, however, is not confined to plane surfaces, it may exist evidently between contiguous surfaces whatever their form. When two segments of a limb, placed in a direct line or nearly so, can be brought to form

* Meckel, Anat. Comp. (Fr. transl.) t. ii. p. 43.

* It may be objected to this arrangement that at the sternal extremity of each cartilage there is a synovial membrane between it and the sternal depression. All anatomists agree in denying its existence at the articulation of the first cartilage, and all admit the great difficulty of fully demonstrating its existence in the others. For my own part I do not believe that it exists in any.

† The articulation of the lower jaw in the whalebone whale, above referred to, is a joint of this kind.

an angle with each other, the motion is that of *flexion*, the restoration to the direct line is *extension*. These two motions belong to what Bichat calls *limited opposition;* the flexion and extension of the fore-arm on the arm illustrate it. Sometimes a motion of this kind takes place in four directions, indicated by two lines which cut at right angles. This is best understood by a reference to the motions which take place at the hip-joint: there it will be seen that the thigh-bone may be brought forward so as to form an angle with the trunk, *flexion*—or it may be restored, *extension;* it may be separated from the middle line of the body so as to form an angle with the lateral surface of the trunk, *abduction*—or it may be restored and made to approximate the middle line, *adduction*. Bichat terms this "*opposition vague*." It is evident that a joint, which is susceptible of these four motions, may also move in directions intermediate to them. When these motions are performed rapidly, one after the other, it appears as one continuous motion, in which the distal extremity of the bone describes a circle indicating the base of a cone whose apex is the articular extremity moving in the joint; this motion is called *circumduction*.

Rotation is simply the revolving of a bone round its axis. It is important to bear this definition in mind: through losing sight of it many anatomists have attributed rotation to a joint which really does not possess it.

The varieties of the diarthrodial joint are as follows:

a. Arthrodia (articulatio plana or *planiformis.)*—In this species the surfaces are plane or one is slightly concave, and the other slightly convex: the motion is that of gliding, limited in extent and direction only by the ligaments of the joint or by some process or processes connected with the bones. The examples in man are, the articular processes of the vertebræ, the radio-carpal, carpal, carpo-metacarpal, inferior radio-ulnar, superior tibio-fibular, tarsal and tarso-metatarsal, temporo-maxillary, acromio-clavicular and sterno-clavicular joints. This last articulation and the wrist-joint possess a greater latitude of motion than the others; the former, in consequence of the shape of its articular surfaces: each surface is convex in one diameter and concave in the other, so that the gliding that takes place in this joint is in the direction of the long and short diameters, which intersect each other at right angles. It is capable, therefore, of vague opposition in those lines, but certainly not in the intermediate directions, the nature of the surfaces being calculated to prevent this. The wrist owes its mobility to the laxity of its ligaments, which permit it to move as well in its transverse as in its antero-posterior diameters, as also in the intermediate directions; it consequently admits of vague opposition and circumduction. The articulation of the metacarpal bone of the thumb with the trapezium, is also an arthrodia very similar to the sterno-clavicular, but with a greater degree of motion. Arthrodial joints are generally provided with ligaments, placed at the extremities of the lines in the direction of which the gliding motion takes place.

b. Enarthrosis (diarthrosis orbicularis—ball-and-socket joint.)—This is a highly developed arthrodia. The convex surface assumes a globular shape, and the concavity is so much deepened as to be cup-like, hence the appellation *ball and socket*. The ball is kept in apposition with the socket by means of a capsular ligament, which is sometimes strengthened by accessory fibres at certain parts that are likely to be much pressed upon. The best example of enarthrosis is the hip-joint, and next to it the shoulder: in the latter the cavity is but imperfectly developed. All the quadrupeds have their shoulder and hip joints on this construction, and the same common plan is observed in the vertebrata generally whose extremities are developed. In birds and reptiles the bodies of the vertebræ are articulated by enarthrosis, and the solid calcareous spines on the external surface of the shells of echinida are adapted to round tubercles on which they move, thus exhibiting a very complete form of enarthrosis.*

This species of joint is capable of motion of all kinds, opposition and circumduction being the most perfect, but rotation limited. Indeed what is called rotation at the hip-joint, is effected by a gliding of the head of the femur from before backwards, and vice versa in the acetabulum; it is not a rotation of the head and neck, but of the shaft of the femur.

c. Ginglymus (γιγγλυμος, cardo, articulatio cardiniformis, articulation en charniere, en genou, hinge-joint.)—The articular surfaces in the hinge-joint are marked with elevations and depressions which exactly fit into each other, so as to restrict motion in all but one line of direction. They are always provided with strong lateral ligaments, which are the chief bonds of union of the articular surfaces.

The elbow and ankle joints in man are perfect ginglymi; the knee also belongs to this class, but is by no means a perfect specimen, for in a certain position of the bones of this joint, the ligaments are so relaxed as to allow a slight rotation to take place. The phalangeal articulations, both of the fingers and toes, are ginglymi. This form of joint is most extensively employed among the lower animals. In quadrupeds, most of the joints of the extremities come under this head. In amphibia and reptiles, too, there are many examples of the hinge-joint. The bivalve shells of conchiferous mollusca are united by a very perfect hinge, and a great number of the joints of crustacea and insects are of this form.

The true ginglymus is only susceptible of limited opposition: hence the knee-joint cannot be regarded as a perfect example; in fact, in the perfect ginglymus there is every possible provision against lateral motion.

d. Diarthrosis rotatorius (commissura trochoides.)—A pivot and a ring constitute the mechanism of this form of joint. The ring is

* Vide fig. 9 in Grant's Comp. Anat. p. 21. See also the article ECHINODERMATA.

generally formed partly of bone and partly of ligament, and sometimes moves on the pivot, sometimes the pivot moves in it. The motion is evidently confined to rotation, the axis of which is the axis of the pivot.

In the human subject the best example of this articulation is that between the atlas and odontoid process of the axis or vertebra dentata. The ring is formed by a portion of the anterior arch of the atlas, completed behind by a transverse ligament. Here the atlas rotates round the odontoid process, which is the axis of motion. Another example is the superior radio-ulnar articulation: here the ring is formed one-fourth by bone, namely the lesser sigmoid cavity of the ulna, and the remaining three-fourths by the round ligament called the coronary ligament of the radius. In this case there is rotation as perfect as in that just mentioned, but the head of the radius rolls in the ring, and the axis of motion is the axis of the head and neck of the bone. Some anatomists consider this joint a species of ginglymus, which they designate lateral.

The terms *Symphysis*, *Synchondrosis*, *Synneurosis*, *Syssarcosis*, *Meningosis*, have been employed by anatomists to designate certain kinds of articulation, chiefly in reference to the nature of the connecting media. Symphysis, although originally employed with great extent of meaning, seems to have been in later days applied exclusively to denote the articulations of the pelvis, which we have classed under Amphiarthrosis. I pass over the other terms, because they ought to be discarded from use, as only tending to encumber a vocabulary already too much crowded with difficult and unnecessary terms.

The descriptive anatomy of the several joints will be found under the heads—ANKLE, CRANIUM, ELBOW, FACE, FOOT, HAND, HIP, KNEE, PELVIS, RADIO-ULNAR, SHOULDER, SPINE, TEMPORO-MAXILLARY, TIBIO-FIBULAR, WRIST, and the morbid anatomy under the head JOINT.

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(R. B. Todd.)

ASPHYXIA. (Gr. Ασφυξια. Fr. *Asphixie*. Ger. *Scheintod*, *Asphyxie*. Ital. *Asfissia*.) The word Asphyxia, according to its derivation (from α and σφυξη, pulsus,) ought to signify what is usually expressed by the term Syncope, i. e. failure of the heart's action; but it is now always used to express failure of the process of respiration.

It is hardly necessary to say, that there is no more general law of vital action, in all classes of organized beings, than its *dependence on oxygen*, i. e. on a certain chemical action taking place between the nourishing fluids of that living body (whether animal or vegetable) and the oxygen of the atmosphere. This law is, indeed, as general as the dependence of vital action on heat, and in like manner as a certain elevation of temperature (short of what acts chemically on the organized textures) is destructive to life, so a certain concentration of oxygen in the air inhaled, at least by the higher orders of animals, affects them as a poison.*

Many organized substances, as the seeds, roots, and stems of vegetables, the pupæ of insects, eggs, even perfect animals of some of the lower classes, may retain their vitality, as is commonly said, i. e. *remain susceptible of vital action*, for very various periods of time, at low temperatures, without exercising any action on the oxygen of the atmosphere; but whenever the *phenomena indicating vital action* take place in them, exposure to oxygen, and a certain alteration of the air surrounding them, very soon become necessary conditions of the continuance of vitality.

The alterations which take place in the air in contact with different living bodies are somewhat various. Water is exhaled probably in every instance. In the case of some animals, particularly fishes, there is certainly an absorption of azote; and in that of vegetables growing under the influence of light, there is a decided absorption of carbon from the carbonic acid of the atmosphere, and an evolution of pure oxygen. But it is now generally agreed, that, in all cases, the action between the atmosphere and the nourishing fluid which is *essential* to the motion and vivifying power of the latter, is that which is denoted by the disappearance of part of the oxygen from the air that comes in contact with that fluid, and the substitution of a quantity of carbonic acid.

Some time since it was the prevalent opinion, that the nature of that action was merely an

* See Broughton in Journal of Science, 1830.

excretion of carbon, which immediately on its being evolved from the nourishing fluid, entered into combination with the oxygen of the air, and was carried off; and the chief reason for this opinion was, that the volume of oxygen which disappeared in the process, was believed to be just equal, in all cases, to that of the carbonic acid that appeared. As it is known that the volume of any quantity of carbonic acid is just the same as that of the oxygen contained in that quantity of acid, if the fact had been as above stated, the coincidence could hardly have been accidental, and the inference would have been nearly inevitable, that the oxygen of the atmosphere did not enter the nourishing fluids, but merely dissolved and carried off the excreted carbon.

But the numerous experiments of Dr. Edwards * and of M. Du Long,† seem to have nearly established the proposition, that in the respiration of by far the greater number of animals, the volume of oxygen that disappears from, is somewhat greater than that of the carbonic acid that appears in, the air employed: the same result was obtained in experiments by Allen and Pepys on *birds*;‡ and if this be so, it is certain that the respiration of these animals is attended with an actual absorption of oxygen, at least to a certain extent.

This conclusion authorizes us to inquire farther, whether it is not more probable, that the whole of the oxygen which disappears from air in contact with the nourishing fluid of living beings, is absorbed into that fluid, and that the carbonic acid which appears is exhaled, ready formed, in its place. And several facts shew that this is by far the more probable supposition; and that oxygen is essential to vital action, not merely as a means of carrying off superfluous carbon, which has become noxious; but *as itself an ingredient in the nourishing fluids, necessary for the maintenance of their motion and vivifying power.*

But without entering at length into this question, which will be more fully discussed under the head of Respiration, it is obvious from what has been said, that provision must be made, in the œconomy of all living beings, for the exposure of their fluids to the air of the atmosphere, in circumstances admitting of exhalation and absorption; and it may be farther stated, that, in the different classes of animals, the amount of this mutual action for which provision has to be made, must be proportioned to the energy and activity of vital action which each animal is destined to exhibit, these qualities being very generally found to be greater, as the consumption and vitiation of the air are more rapid.§

These principles explain the intention of many different contrivances and arrangements, afterwards to be described, which are employed in different classes of animals for the performance of the function of respiration; and the variations of which may be said, in a general view, to be determined by two conditions, first by the medium in which each animal is destined to exist, and secondly, by the intensity and variety of vital actions which it is to be capable of performing.

The importance, to all living beings, of the action of oxygen on their fluids is most unequivocally shewn by the nature of the fatal changes which ensue, when that action is in any way obstructed; i. e. by the nature of the changes which take place in *death by asphyxia.* The study of these has long been held to be of the highest importance, not only as a cardinal point in physiology, but as affording the only precise information in regard to the fatal tendency of many and various diseases.

It is chiefly in animals of the highest orders, i. e. in warm-blooded animals, that these phenomena have been studied; and it is to be remembered, that in them the subject is rendered more complex by the higher endowments and greater power over all functions of the body, which the nervous system there possesses. When we trace the connection, in these animals, of the different changes that precede the fatal event, it is right to bear in mind, that the interruption of the process by which their fluids are exposed to the air is equally fatal, not only to those animals in which no action of the nervous system is concerned in that process, but also in vegetables, where no nervous system exists.

The phenomena of asphyxia in the higher animals are very nearly the same, in whatever manner the access of air to the organs of respiration is prevented. This may be done, in the case of animals that breathe by lungs, in a great variety of ways; by strangulation or suffocation, i. e. by any mechanical means prohibiting the ingress of air by the trachea and bronchi; by submersion in water or any other fluid; by confinement in vacuo or in such gases as contain no oxygen, but are not themselves poisonous, such as azote and hydrogen; by forcible compression of the thorax, preventing its dilatation; or by the admission of air into free contact with the surface of the lungs on both sides of the chest, so as to prevent their distension, as in the celebrated experiment of Dr. Hooke; or by the section, either of all the separate nerves which move the muscles concerned in the dilatation of the thorax in inspiration, or of the spinal cord in the upper part of the neck, above the origin of the phrenics, by which the whole of these nerves are simultaneously palsied, as in many experiments of Galen, Cruikshank, Le Galleis, and others.*

In the case of fishes or other animals that

* De l'Influence des Agens Physiques sur la Vie, p. 410, et seq.

† Journal de Physiologie, t. iv.

‡ See Hodgkin's Translation of Edwards, p. 486.

§ See Cuvier, La Règne Animale, t. i. p. 56; also Marshall Hall, Philosophical Transactions, 1832, p. 339.

* These last are the lesions of the nervous system which cause sudden death by asphyxia. Section of the par vagum, the sentient nerve of the lungs, produces death by asphyxia also, but slowly, and through the intervention of disease and disorganization of the lungs, to be afterwards noticed.

breathe by gills, where several of the methods above enumerated are inapplicable, asphyxia is produced, either by confinement in air, or in distilled water, or water impregnated with any gas that does not contain oxygen; for no animal has the power of decomposing water by its organs of respiration, to obtain oxygen, and all aquatic animals are dependent, either on the occasional respiration of atmospheric air by lungs, or on the more constant respiration of the air contained in water by gills or analogous organs.

In the case of fishes breathing by gills, as the motion of these organs is dependent on nerves arising as high as the medulla oblongata, injury of the nervous system must be as high as that part, in order to produce asphyxia; and on the other hand, in the case of birds, where the expansion of the thorax in inspiration is effected almost entirely by the motion of the ribs, asphyxia may be produced by section of the spinal cord in any part of the neck.*

We exclude here entirely the cases, often described under the name of asphyxia, in which gases positively noxious (such as carbonic acid, carburetted hydrogen, &c.) have been breathed, because accurate observation shows that these are in fact cases of poisoning, where the poison has been introduced by the lungs, and not simply cases of asphyxia.

The phenomena of asphyxia, in all the cases above-mentioned, (as occurring especially in the warm-blooded animals,) may be divided into three stages. The first is characterized by the intensity of the sensation which prompts to acts of inspiration, and the consequently violent and laborious, though ineffectual attempts to appease that sensation by the action of all the muscles of inspiration; and in some instances by other actions, voluntary or instinctive, but still under the guidance of sensibility. Lividity of the surface takes place before the end even of this stage. The next is distinguished by insensibility, rapidly increasing, and attended with irregular spasms or convulsions; and the last by cessation of all effort, and of all outward signs of life, while the heart's action and circulation are known still to go on for a short time.

In the case of a warm-blooded animal (excluding the cetacea, and animals that habitually dive) in the full possession of its vital powers, exposed to complete and sudden obstruction of the access of air to the lungs, it may be stated, that the two first of these stages are very generally over within three minutes, seldom extending to five, and that the circulation through the heart has very generally ceased within less than ten minutes from the commencement of the obstruction. The time during which the privation of air can be borne may be somewhat extended by habit; and there are instances of men trained to diving in India who have remained under water three, four, or even five minutes without loss of sensibility or subsequent injury.

* Flourens in Annales d'Histoire Naturelle, t. 13.

In cases of disease, terminating in death by asphyxia, all these stages may often be observed to be distinctly gone through, although in a very gradual and somewhat irregular manner; the dyspnœa and lividity being succeeded by delirium, often by spasms, and ultimately by coma, and the respiration coming to a stand in general a little before the action of the heart.

The most characteristic appearance which is seen after death by asphyxia, is simply the great accumulation of blood in the vessels of the lungs, in the pulmonary artery, right side of the heart, and great veins, and the comparatively empty state of the left side of the heart, the larger pulmonary veins, and the aorta. The left ventricle is not found empty after death, but seldom contains half as much blood as the right; and it is in this part of the heart that the contractions are soonest observed to cease. The accumulation of blood in the lungs and right side of the heart is greatest in cases where the asphyxia has been gradual, the access of air to the blood not having been absolutely obstructed.*

Besides this appearance of congestion of blood in the thorax, the liver, the spleen, and the whole venous system in the abdomen, are generally observed to be unusually congested in such cases, especially those parts which are *depending* after death; and even ecchymosis on the mucous membrane of the stomach, after strangulation, has been observed by Dr. Yelloly and others. This congestion of blood in the liver, and in the veins of the abdomen, is remarkably observed, and leads to important consequences, in various chronic diseases of the thorax, threatening death by asphyxia.

The blood after this, as after other kinds of sudden or violent death, is usually found fluid, and very imperfectly coagulated; and in connection with this state of the blood there are frequently livid marks resembling ecchymosis, (though not depending on extravasation of blood,) in various parts of the surface of the body, and not exclusively in depending parts. This appearance is, of course, most remarkable in the face and neck after strangulation, and is much less observed on any part of the surface after drowning.

After strangulation, if the body is soon examined, congestion of blood in the vessels of the brain and pia mater may often be remarked, but there is seldom any morbid effusion. After drowning, a frothy fluid, in consequence of the introduction of a small quantity of water, and of efforts at respiration, is generally found in the trachea and bronchi.

The successive steps by which physiologists have been led to what we may regard as a satisfactory account of the phenomena now described, and of the death by asphyxia, may be recapitulated, as curious in themselves, and as affording the clearest view of the evidence on which the doctrine, which now appears to be well founded, is supported.

* Bichat, Recherches Physiologiques, &c. (4th edit.) p. 333.

1. The first opinion on this subject, which need be noticed here, is that which was supported by the great Haller, viz. that the circulation, and with it all other functions of the body are brought to a stand, because when the movements of respiration cease, and the lungs are no longer dilated and contracted, there is a mechanical difficulty to the propulsion of the blood through the pulmonary capillaries, by which the fatal stagnation in these vessels, obvious on dissection, is produced.

This doctrine was satisfactorily refuted by Goodwyn, in his treatise on the Connection of Life with Respiration, who shewed that the air-cells of the lungs are not necessarily contracted at the time of asphyxia, and that after having once admitted air, these cells never are so much emptied of it again, or contracted on themselves, as to offer any considerable impediment to the free motion of blood in their parietes. Besides, we know that the same stagnation in the lungs takes place in the case of an animal confined in a gas which does not contain free oxygen, as in the case of drowning or strangulation, although in the former case, any impediment to the mechanical acts of respiration that can occur, must be the consequence, not the cause, of the fatal changes within the chest.*

2. The well-known theory of Goodwyn himself on this subject was, that the venous blood is not an adequate stimulus to the left side of the heart, which in the natural state circulates arterial blood only, and which fails to contract upon or propel blood which has passed unchanged through the lungs.†

This doctrine was, in its turn, refuted by Bichat, who showed by experiment that in the case of strangulation the venous blood does penetrate the lungs and left side of the heart, and is delivered from the carotid arteries if these are punctured; that the appearance of venous blood in these arteries is contemporaneous with what was described as the second stage of asphyxia, viz. the insensibility and spasms; and further, his experiments have been generally admitted as affording satisfactory evidence, that the circulation of venous blood through the brain is a sufficient cause for these symptoms, and produces them when the venous blood from the heart of one dog is sent to the brain of another.‡ He also found by experiment, that venous blood could be injected artificially into the left cavities of the heart, with the effect of exciting, not suppressing their action.§

3. Bichat ascribed the cessation of the circulation in asphyxia, however, not to the penetration of the brain by venous blood, and the consequent insensibility (which is now well known to be compatible with the maintenance of circulation for many hours, provided the blood can be arterialized,) but to the penetration of the muscular substance of the heart by venous blood, sent to it by the coronary arteries, and which he held to be equally (although less rapidly) fatal to the vital action of this organ, as of the brain or nerves.

4. Later experiments and observations have, however, shewn that this explanation likewise is, in some measure, incorrect. In fact, while the free flow of venous blood in the carotid arteries of an asphyxiated animal was urged with perfect fairness by Bichat, as a refutation of the theory of Goodwyn, it was with equal justice argued by Goodwyn,* in opposition to Bichat, that if the heart's actions ceased in asphyxia, only because its substance is penetrated by venous blood from the coronary arteries, these actions could not be restored by blowing air into the *lungs* and arterializing the blood *there*.

Bichat, indeed, foreseeing this objection, maintained that the artificial respiration never is successful in restoring the circulation, unless employed in the interval which, as was already stated, always exists between the occurrence of insensibility and the final cessation of the circulation. But subsequent and careful observations (e.g. those of Roesler, Edinburgh Journal, vol. xxiii) show that life has been restored, by this means, after warm-blooded animals have lain from twelve to seventeen minutes after their immersion in water, i. e. until a time when all observations made by laying open the chests of similar animals show that their circulation must have ceased. The records both of the Humane Society in London and of a similar institution in Paris, seem sufficiently to show that resuscitation has occasionally taken place in the human body after fifteen minutes' immersion.† And we are therefore well assured that the arterialization of the blood at the lungs may, in some instances, restore the natural state of the heart's action after the circulation has come to a stand.

Farther, although there is a laboured attempt, by Bichat,‡ to explain the accumulation of blood on the right side of the heart, and the comparative emptiness of the left side, in asphyxia, consistently with his own explanation of the failure of the circulation; yet it seems obvious, that if that explanation were correct, the left side of the heart, receiving the venous blood and contracting on it until it loses its power from the penetration of its own fibres, should be found after death distended with that blood; and that the accumulation of blood taking place in the lungs and right side of the heart, indicates that the *capillaries of the lungs* are the main seat of the cause which ultimately stops the circulation.

That this is really the fact has been more unequivocally shown, first, by the experiments by Dr. Williams, and afterwards by those of

* This point has been further elucidated by some experiments, of which an account was read, by the author of this article, to the Medical Sections of the British Association.

† Connexion of Life with Respiration, p. 82.

‡ Recherches Physiologiques, &c. Art. vii.

§ Recherches, &c. p. 327.

* In a paper, not published till after his death, but contained in the Edin. Med. and Surg. Journal, July 1830.

† See Cyclopædia of Practical Medicine, art. Asphyxia.

‡ Recherches, &c. art. 6.

Dr. Kay,* which we know to have been carefully performed, and sufficiently repeated, and which appear to solve satisfactorily all the difficulties that have been stated. Bichat had not adverted to the *length of time* during which the circulation of venous blood by the left side of the heart, is carried on in asphyxia; but the experiments of both Dr. Williams and Dr. Kay prove, that this time is very short, and that before this side of the heart has lost its contractile power, *the pulmonary veins have ceased to deliver the blood* to it, in such quantity as to maintain any effective action. A short quotation from Dr. Kay's paper will show the evidenee for this proposition.

"Experiment 1. The trachea of a large rabbit was tied, the abdomen and chest opened, and at the end of the second minute from the commencement of the experiment, the external iliac artery was divided; a considerable quantity of dark blood flowed, but at the third minute it had almost ceased to escape. The heart continued contracting vigorously; very small quantities of dark blood collected slowly every twenty seconds at the extremity of the artery. In five minutes all flow of blood had entirely ceased. *The left heart contracted spontaneously for a very considerable period longer.* I repeated this experiment with similar results."† Again, one of the variations of the experiment was as follows: "Experiment 3. A rabbit was asphyxiated by tying the trachea. The chest was opened. At the end of three minutes and a half no pulse could be discovered in the aorta. The left auricle was then opened, the blood contained escaped, and for a period of from one to three minutes, blood occasionally eollected in very minute quantities, as though it gradually drained from the larger vessels of the lungs, *but never, as often as the experiment was repeated, collected in quantity.* The heart continued vigorous the usual period."

"In general," says Dr. Kay, "the phenomena of the cessation of motion in the left heart in asphyxia are these. A smaller quantity of blood is received into its cavities, and expelled for a time vigorously into the arteries. The ventricle meanwhile diminishes in size, as the quantity of blood supplied becomes less, until at length, although spontaneous contractions still occur in its fibres, no blood issues from a divided artery, *and the ventricle, by contraction, has obliterated its cavity.* After this, blood slowly accumulates in the auricle from the large vessels of the lungs; and its contractility continues for a very eonsiderable period."‡

Farther experiments by Dr. Kay show, that after the aorta of an animal has been tied, and after the muscles of its lower extremities have, in consequence, gradually lost all contractile power, that power is restored for a time by the injection of *venous* blood into the lower portion of the aorta; § and from these, and from some experiments by Dr. Edwards,* we learn, that the venous blood, though less powerful than arterial in maintaining the vital power of muscles, is by no means rapidly destructive to it.

The changes in asphyxia, in the warm-blooded animals, have, therefore, of late been generally thought to be as follows:—that the venous blood, though more or less noxious to all parts of the body which it fully penetrates, is nevertheless transmitted through the lungs in the first instance, in sufficient quantity to stimulate the left side of the heart, and is sent from thence in sufficient quantity to penetrate the brain;—that by its action there it destroys the sensibility, but that it passes more and more slowly through the pulmonary vessels, and after a few minutes is no longer delivered to the left side of the heart in such quantity as to keep up regular and efficient contractions there; and that thus, while the *animal* life is suddenly extinguished by the noxious influence of venous blood on the brain, the *organic* life is more gradually brought to a stand by its noxious influence in the lungs, and the consequent failure in the supply of blood to the left side of the heart.

This explanation is consistent with all the phenomena, and particularly with the *very rapid* restoration of the flow of blood by the admission of air to the lungs of half-asphyxiated animals, stated by Bichat himself as a difficulty in his view of the subject.

The more reeent experiments by Dr. Kay had, however, led him to question the validity, even of that part of Bichat's doctrine, which has been most generally admitted, viz. the rapidly noxious effeet of venous blood on the brain and nerves. He found, in various cases, that large quantities of blood from the veins of one rabbit could be injected (*slowly and cautiously*, so as to avoid all injury of the cerebral matter) into the carotid arteries of another, without causing more than muscular debility and lassitude; so that he considers venous blood to be only a weaker stimulus to the brain than arterial, not a direct poison to it; and thinks the *sudden insensibility* of asphyxia is to be explained by the rapid diminution of the quantity, not by the change of quality, of the blood sent to the brain from the heart.†

And when we bear in mind the faet stated in the outset of this inquiry, that the motion and vivifying power of the nutritious fluid is dependent on its exposure to oxygen, not only in the higher animals, but even in the lowest tribes, and in vegetables, where neither heart nor nervous system exists; it appears reasonable to suppose, that the chief impediment to the blood's motion, from the failure of the supply of oxygen, will be *in the lungs themselves*, where the venous blood is accumulated in the greatest quantity, and where all the minute vessels carrying it must be most completely exposed to its action.

But before we can be completely satisfied upon this subject, it will be necessary to carry the inquiry one step further, and to ascertain in what manner the change from venous to

* Edinburgh Medical and Surgical Journal, vol. xix. and xxix.

† Edinburgh Journal, vol. xxix. p. 42.

‡ Ibid, p. 46.

§ Ibid, p. 53 and 54.

* De l'Influence, &c. p. i. ch. i. and p. iv. ch. 4.

† Treatise on Asphyxia, p. 193 et seq.

arterial blood so greatly promotes the flow of blood through the capillaries of the lungs, and how the presence of venous blood in the beginnings of the pulmonary veins can so effectually retard it, that the action of the right ventricle of the heart, though continuing vigorous for a time thereafter, fails of its wonted effect, and the blood stagnates in those capillaries.

The common expression employed on this subject is, that arterial blood is a stimulus peculiarly adapted to excite the capillaries of the lungs and pulmonary veins; and that venous blood stagnates in those capillaries for want of power to excite them. But it must be remembered that we have no distinct evidence of the existence of coats, still less of irritable coats in the minute capillaries of the lungs;* that although the circulation there has been often examined with the microscope, no contraction of the vessels has ever been observed; that the only vital power of contraction which experiments authorize us to ascribe to any arteries, is a power of permanent or tonic contraction on their contents, which, when called into action, lasts for some time, and while it lasts must obviously impede the flow of fluids through these vessels; that on these grounds Magendie and other eminent physiologists believe the only power, which arteries can exercise over their contents, to be simply a power of either relaxing, so as to give them a free passage, or contracting so as to lessen and retard their flow;† and that, conformably with these views, it was found by Wedemeyer, that when he injected stimulating liquids into the arteries of living animals, they were much longer of making their way into the veins, than mild liquids were.‡

These considerations evidently point to the conclusion, that, if the difference depend on any vital action of vessels, venous blood, which makes its way so slowly through the capillaries of the lungs, must be the stronger stimulus to them, and that arterial blood, which is transmitted so readily, must act as a sedative, to the only vital action of which these vessels are susceptible. But this conclusion is again strongly opposed by the fact, that in all other instances, in relation to muscular contraction, to the functions of the nervous system, and of secreting organs, arterial blood, and the oxygenated fluids in general, manifestly possess the stimulating power, and venous blood or carbonized fluids the sedative.

In this difficulty it is important to remember, that we have many facts to indicate the existence of powers which move the blood and other organized fluids in living animals, independently of any contractions of moving solids. It would appear that the power by which any texture is nourished, or secretion or excretion is formed from the blood, in any part of the circulation, is, to a certain degree, a cause of movement of the blood towards that part, and that any stimulus given to such act of nutrition or secretion, although applied at the extremity of the capillaries, produces an effect on the circulation which, as Sir C. Bell expresses it, is *retrograde along the branches* of the arteries. Thus, the flow of blood to the mucous membrane of the stomach and bowels during digestion, to the uterus during gestation, to the mammæ during lactation, to any part of the body during inflammation, suppuration, or the growth of a tumour, is excited by causes acting at the extremities of the arteries of these parts; although there is the same difficulty in all these cases, as in the case of the lungs, in understanding how a cause acting there, and exciting the only vital power which arteries can be shewn to possess, should increase the flow of blood through them.

It is always to be remembered, that precisely analogous phenomena are observed from the application of heat, or other stimuli, to single branches, or roots, of vegetables, where there is no evidence of the existence, either of a structure or of a contractile power, in the vessels or cells through which the fluids pass, capable of giving them a determinate direction towards the parts, which are thus stimulated; and where the movement of fluids that can be seen, (in the case of those plants that have milky juices,) is not only unattended with any visible contraction of solids, but is of a kind, (as the recent observations of Schultze, Amici, Raspail, and others indicate,) which no contractions of solids appear capable of producing.

It is farther to be observed, that when venous blood becomes arterial, it acquires an increase of fibrin,* and that its tendency to coagulation is decidedly increased,† which implies such an increase of an attraction of aggregation in the particles of the fibrin, as may be held to be strictly vital. And on the other hand, when arterial blood becomes venous, according to the microscopical observations of Kaltenbrunner, its globules seem to separate somewhat from one another, and its whole bulk appears somewhat increased.‡

Lastly, it is to be remembered, that when a vessel is opened in a living animal, and the blood exposed to the air, the consequence is, a movement of *derivation* of the blood, in all directions, towards the aperture; which is certainly altogether independent of the heart's action, and which the elaborate investigations of Haller led him (and apparently with good reason) to think inexplicable likewise by any contraction of vessels.§

The consideration of all these facts may lead us strongly to suspect, that the stimulus to the circulation which is given by the arterialization of the blood, and which we have found to act chiefly in the capillaries of the lungs, is of the nature of an *attraction* of the venous blood towards the part where it is to

* See Marshall Hall on the Circulation, p. 47.

† Physiology, translated by Milligan, p. 409-10. Mayo's Outlines, (2nd edit.) p. 87 et seq.

‡ Edinburgh Medical Journal, July 1829, p. 90.

* Prevost and Dumas, An. de Chimie, t. xxiii.

† See particularly Schrœder Van der Kolk, Com. de Sanguine Coagulante.

‡ Experimenta circa Statum Sanguinis, &c. § 281 & 357.

§ Mem. sur le Mouvement du Sang, p. 336 et seq.

undergo this change, and towards the arterial blood in advance of it in the vessels; not of the nature of an increased *contraction* of the vessels themsleves; and that it is in consequence of the failure of this *auxiliary power* in the circulation, that the stagnation of the blood in the lungs in asphyxia, and the extinction of the organic life, are effected.

What has been said of the manner in which death is produced in asphyxia, enables us to understand in what circumstances it can happen, that life may be retained, even by a warm-blooded animal, for an unusual length of time, without respiration. As the stop to the circulation is the immediate cause of death, it is obvious that an animal which can exist for a time, in a lowered state of vitality, with little or no circulation, will during that time require no exposure of its blood to air, to maintain that grade of vitality; and farther that in such an animal, as the brain will not suffer from the afflux of venous blood, and as the lungs will not be hurtfully congested, these organs will retain a condition much better adapted for the recovery of their functions, than they will in those cases where asphyxia is produced at a time when the circulation is vigorous.

Hence we can easily understand, that persons who are in a state of syncope, (from a temporary cause,) in whom the circulation is nearly at a stand before the access of air to their lungs is obstructed, may survive a longer suspension of the acts of respiration than persons in health. This has been stated, by Des Granges and Foderé, as the explanation of some cases in which it appears certain, that recovery has taken place after fifteen minutes or more of submersion in water.*

The case of hybernating animals was, until lately, considered to be of this nature, i. e. it was supposed that circulation is gradually suspended in those animals, simultaneously with respiration, and therefore that such animals, although consuming little or no air, did not suffer the noxious influence of venous blood on their solids, and remained susceptible even of sensation. But the experiments of Dr. Marshall Hall † appear to have established that in warm-blooded hybernating animals in the complete state of torpor, when respiration is quite at a stand for many hours, circulation, although slow and feeble, still goes on regularly; so that we must suppose the essential peculiarity of these animals, during the state of lowered vitality, to which they are reduced by cold, to be this, that the venous blood has little of the noxious effect, in any part of the system, which it has, on them as on other animals, during the state of activity; it has neither the same difficulty of making its way through the lungs, nor the same destructive influence on the brain.‡

The nearest approach to this mode of vitality in the human body, is in the case of the new-born child, which has never felt the influence of perfectly arterial blood, and which has been known to live, although its natural respiration was not established for nearly an hour after birth.

The study of the fatal changes in asphyxia is also of peculiar importance as illustrating the manner in which the circulation, and the organic functions maintained by it, are connected with the nervous system. It will be observed, that as the vitality of hybernating animals, during the state of torpor, is independent of respiration, so it is also, in a great measure at least, independent of the larger masses of the nervous system; and Dr. M. Hall found, by experiment in a hedgehog in this state, that the circulation went on regularly for *ten hours* after the gradual but complete destruction of the brain and spinal cord.

Indeed, the maintenance of the circulation after the head of an animal has been cut off, by the artificial respiration, i. e. by inflating its lungs in a manner resembling its natural breathing, (which has been so often practised by Fontana, Cruikshanks, Bichat, Brodie, Le Gallois, Wilson Philip, and others,) is in itself a clear proof that the circulation, and other functions of *organic* life* in animals, are necessarily and immediately dependent on the *animal* life, only inasmuch as the natural respiration of animals, and the arterialization of their blood, are dependent on sensation. And accordingly we know, that in that stage of animal existence, where the supply of sufficiently arterialized blood is provided for without the intervention of sensation, i. e. in the fœtus in utero, the whole organic life is altogether independent of the animal, and goes on perfectly, not only before sensation is felt, but even in cases where the essential organs of sensation and of voluntary motion, the brain and spinal cord, do not exist. It is not until the moment of birth, when the arterialization of the blood is put in dependence on sensation,—that the brain and spinal cord become essential for the maintenance of organic life; or that we possess any proof of influence being exercised by the nervous system, over that part of the animal œconomy.

It seems probable, that if we possessed the means of making the artificial respiration exactly similar to the natural, and neither injuring the structure of the lungs, nor introducing more air into them than is useful, in practising it, the circulation, and perhaps all the functions of organic life, might be maintained, after the head of an animal is cut off, until nearly the time when it must fail for want of nourishment; but it must also be remembered, that in the adult animal, as the experiments of Le

* Foderé, Med. Legale, § 613.

† Phil. Transactions, 1832.

‡ Dr. M. Hall considers the essential peculiarity of these animals to be, that the left side of the *heart* in them, is irritable by venous blood; but as it appears from the facts above stated, that the stop to the circulation in asphyxia is at the *lungs*, the chief peculiarity of these animals must lie there also.

* By organic life, we mean those vital acts which take place without the intervention or consciousness of the mind; by animal life, those in which some mental act is an essential constituent.

Gallois, Dr. Wilson Philip, Flourens, and others have shewn, injuries of the brain and spinal cord, (particularly injuries *suddenly* inflicted on any *large* portions of these organs,) may directly influence, or even wholly suppress, vital actions belonging to the head of organic life, for the performance of which we have no evidence of their furnishing any necessary condition.

As the function of respiration thus appears to be the only link by which the organic life is immediately and necessarily connected with animal life, it is naturally to be expected that the extinction of animal life should affect the organic functions just in the same way as the suspension of respiration does, and therefore that in the case of death beginning at the brain, as Bichat expressed it, (*i. e.* of death consequent on the extinction of sensation and voluntary motion,) the circulation and other organic functions should be brought to a stand just in the same manner as in death by asphyxia. And in what is strictly called death by coma, this is really the case; the sensations being gradually more and more impaired, the sense of anxiety in the chest, which prompts to the acts of respiration, is ultimately extinguished; but even after the last breath has been drawn, the pulsations of the heart still continue, and the blood then gradually stagnates in the lungs, the circulation comes to a stand, and the blood is found after death congested on the right side of the heart, just as in the case of asphyxia already described.

That this is truly the mode of fatal termination in cases where death takes place strictly in the way of coma, was first unequivocally proved by Sir B. Brodie,* who found, by experiment, that animals poisoned by opium or other narcotics, and in which the acts of respiration had ceased, in consequence of the impression made on the brain and the gradually increasing insensibility, might be recovered by the artificial respiration, just as asphyxiated animals may be. Indeed the same expedient had been previously employed with success (although not suggested by an equally accurate view of its mode of action) by Mr. Whately.†

The reason why the same expedient cannot be expected to avail in cases of *disease* terminating by coma is simply that in these cases the cause of the coma is not temporary, like the effect of a narcotic poison, but permanent. It seems possible that it may yet be found successful in some cases of insensibility with convulsion, in children, unconnected with organic lesion.

In so far, therefore, as the extinction of the organic life is concerned, the death by coma, or beginning at the brain, resolves itself into the death by asphyxia, or beginning at the lungs, the difference lying merely in the mode in which the arterialization of the blood is arrested.

But although this is strictly true as to cases of violent death, produced experimentally in such a way that a single cause only is allowed to operate; and although we occasionally meet with cases of equal simplicity in disease, and ought always to keep in view the principles which these simple cases illustrate in the treatment of disease, yet it ought not to be supposed that either the death by asphyxia, that by coma, or that by syncope, often present themselves to the observation of the medical practitioner in the same simplicity as to the experimental physiologist. We can state from frequent observation, that it is only in a certain number of cases of disease, strictly belonging to the head, such as apoplexy or hydrocephalus, that death takes place exactly in the way of coma, as above described, or that the function of circulation can be observed to survive that of respiration; and on the other hand there are many instances of disease of the lungs, particularly of phthisis, in which the ultimate extinction of life is rather in the way of syncope than of asphyxia. The simple principle, that the circulation, though not dependent on any action of the nervous system, is liable to be influenced in various ways by causes acting on the nervous system, enables us to understand that death may often take place, in the course of diseases, in a way different from that which the seat of the disease may lead us to anticipate.

Nevertheless it may often be of real and practical importance, with the view of acquiring clear and precise ideas of the modes of fatal termination which are to be expected in the course of diseases, and particularly of such diseases as fever—where the symptoms immediately preceding death, and the causes evidently inducing death, are remarkably various in different individual cases,—to study attentively the phenomena, and causes, of the fatal termination, in the simpler cases of violent death, such as those which have been here considered.

* Phil. Transactions, 1812.

† London Medical Observations and Inquiries, vol. vi.

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(W. P. Alison.)

AVES, birds; (Gr. Ορνιθες; Fr. *Oiseaux*; Germ. *Vögeln*; Ital. *Uccelli*:) a class of oviparous vertebrate animals, with warm blood, a double circulation, and a covering of feathers.

Birds are organized for flight, and as this, the most vigorous kind of locomotion, demands the greatest energy in the contractility of the muscular fibre, so the respiratory function finds its highest development in the present class. Not only the ramifications of the pulmonary artery, but many of the capillaries of the systemic circulation, from the singular extension of the air-cells through the body, are submitted to the influence of the atmosphere, and hence birds may be said to enjoy a double respiration.

Although the heart resembles in some particulars that of the *Reptilia*, the four cavities are as distinct as in the *Mammalia*, but they are relatively stronger, their valvular mechanism is more perfect, and the contractions of this organ are more forcible and frequent in Birds in accordance with their more extended respiration and their more energetic muscular actions.

As Birds exceed Mammals in the activity of those functions on which the waste and renovation of the general system more immediately depend, so they possess a higher standard of animal heat: their ordinary temperature is 103° and 104°, and according to Camper is occasionally as high as 107° Fahr.

The modification of the tegumentary covering characteristic of the present class is to be regarded rather as dependent upon, than occasioning, this high degree of internal temperature, which requires for its due maintenance against the agency of external cold an adequate protection of the surface of the body by means of non-conducting down and imbricated feathers; and this warm clothing is more especially required to meet the sudden variations of temperature to which the bird is exposed during its rapid and extensive flights.

The generative product is always excluded from the oviduct in an undeveloped state, inclosed, in a liquid form, within a calcareous case or shell. The female organs are, therefore, developed only on the left side of the body. The ovum is subsequently perfected by means of *incubation*, for which action the bird is especially adapted by its high degree of animal heat.

Birds form the best characterized, most distinct, and natural class in the whole animal kingdom, perhaps even in organic nature They present a constancy in their mode of generation and in their tegumentary covering, which is not met with in any other of the vertebrate classes. No species of Bird ever deviates, like the Cetacea among Mammals, the Serpents among Reptiles, and the Eels among Fishes, from the tetrapodous type of formation which so peculiarly characterizes the vertebrate division of animals.

The anterior extremities are invariably constructed according to that plan which best adapts them for the actions of flight; and although, in some few instances, the development of the wings proceeds not so far as to enable them to act upon the surrounding atmosphere with sufficient power to overcome the counteracting force of gravity; yet, in these cases they assist, by *analogous motions*, the posterior extremities; either, as in the Ostrich, by beating the air while the body is carried swiftly forward by the action of the powerful legs; or, as in the Penguin, by striking the water after the manner of fins, and by the resistance of the denser medium carrying the body through the water in a manner analogous to that by which the birds of flight are borne through the air. In a few exceptions only are the wings reduced to mere weapons of offence, as in the Cassowary and in the singular Apteryx of New Zealand, in which they are represented by a single spur. In no instance do the anterior extremities take any share in stationary support or in prehension.

Birds are therefore biped, and the operations of taking the food, cleansing the plumage, &c. are almost exclusively performed by means of the mouth, which consists of two unlabiate and edentate mandibles, sheathed with horn. To facilitate the prehensile and other actions thus transferred to the head, the neck is elongated, and the body generally inclined forwards and downwards from the hip-joints. The thighs are accordingly extended forwards at an acute angle from the pelvis towards the centre of the trunk, and the toes are lengthened and spread out to form an adequate base of support. The actions of perching, walking, running, scratching, burrowing, wading, and swimming, require for their perfect performance different modifications of the posterior extremities. The mandibles, again, present as many varieties of form, each corresponding to the nature of the food, and in some degree indicative of the organization necessary for its due assimilation. Ornithologists have, therefore, founded their divisions of the class chiefly on the modifications of the bill and feet. Since, however, Birds in general are associated together by characters so peculiar, definite, and unvarying, it becomes in consequence more difficult to separate them into subordinate groups, and these are necessarily more arbitrary and artificial than are those of the other vertebrate classes.

A *binary* division of the class may be founded on the condition of the newly-hatched young, which in some orders are able to run about and provide food for themselves the moment they quit the shell *(Aves præcoces)*; while in others the young are excluded feeble, naked, and blind, and dependent on their parents for support *(Aves altrices)*.

Scopoli, in his 'Introduction to Natural History,' published in 1777, proposed a dichotomous systematic distribution of Birds, founded on the form of the scales covering the tarsus. The species which have these scales small and polygonal are the *Retepedes* of this author; those which have the legs covered anteriorly with unequal semicircular plates are the *Scutipedes*.

Nitzsch,* the celebrated professor of natural history at Halle, has synthetically grouped together the feathered tribes under *three* grand orders, according to the great divisions of the terraqueous globe which form the principal theatres of their actions.† The first *order* consists of the birds of the air *par excellence*, *Aves aereæ* (Luft-vögeln); the second order embraces the birds of the earth, *Aves terrestres* (Erd-vögeln); the third great division includes the birds which frequent the waters, *Aves aquaticæ* (Wasser-vögeln). The Eagle and the Sparrow may be named as examples of the first; the Ostrich and the common fowl of the second; the Heron and the Gull of the third of these extensive divisions.

A more definite arrangement of Birds, in which a similar principle may be traced, has been proposed by a distinguished naturalist of our own country, Mr. Vigors. He divides the class *Aves* into *five* orders. The *first* includes the birds which soar in the upper regions of the air, which build their nests and rear their young on the highest rocks and loftiest trees, and which may be regarded as the typical species of Nitzsch's *Aerial Birds*; this order is termed *Raptores*, from the rapacious habits and animal food of the species so grouped together.

The *second* order affects the lower regions of the air; the birds composing it are peculiarly arboreal in their habits, and are therefore termed Perchers or *Insessores*.

The *third* order corresponds to Nitzsch's *Aves terrestres*, and is denominated *Rasores*, from the general habit which these granivorous species present of scratching up the soil to obtain their food.

By dividing the aquatic birds of Nitzsch into those which frequent the fresh waters, and are limited to wading into rivers, lakes, &c. in search of their food, and those which possess the power of swimming in the great ocean, we obtain the two remaining orders of the quinary arrangement of Mr. Vigors, viz. the *Grallatores*, or Waders, and the *Natatores*, or Swimmers. The merit of this system is not, however, confined to the defining of the different groups in as clear and readily appreciable a manner as the subject will admit; but it also aims at displaying the natural affinities by which the several orders and families are connected with and pass into one another. In the ornithological systems of other naturalists, who have made this branch of zoology their particular study, we find the greatest discrepancy both as to the number and value of the primary divisions of the class.

Sandewall has *four* orders or cohorts.
Vieillot, like Vigors, has *five* orders.
Linnæus, Cuvier, Carus, and Dumeril have *six* orders.
Illiger has *seven*.
Scopoli, Latham, Meyer, Wolf and Blainville have *nine*.
Temminck (1820) has *sixteen*.
Schœffer has *seventeen*.
Brisson has *twenty-eight*, and
Lacepede has *thirty-eight* orders.

Where so many masters of the science differ, it is difficult for one less profoundly versed in ornithology to select the most unexceptionable system of arrangement, and as Kirby* observes, 'the choice perplexes.' We have here adopted the arrangement proposed by that distinguished naturalist as being the one which facilitates the expression of the leading anatomical differences which obtain in the class of Birds, and which may therefore be considered as the most natural.

Orders.

I. Raptores, Vig. *Syn. Accipitres*, Linn. Cuv. Birds of Prey or Raveners.†
II. Insessores, Vig. *Passeres*, Linn. Cuv. Perchers.
III. Scansores, Illig. Cuv. Climbers.
IV. Rasores, Illig. *Gallinæ*, Cuv. Scratchers.
V. Cursores, Illig. *Brevipennes*, Cuv. Coursers.
VI. Grallatores, Illig. *Grallæ*, Linn. Cuv. Waders.
VII. Natatores, Illig. *Palmipedes*, Cuv.; *Anseres*, Linn. Swimmers.

The following are the characters of these orders.

Class Aves *(Birds.)*

Animal vertebrated, oviparous, biped.
Anterior extremities organized for flight.
Integument plumose.
Blood, red, warm.
Respiration and *circulation* double.
Lungs fixed, perforated.
Negative characters, no auricles, lips, teeth, epiglottis, diaphragm, fornix, corpus callosum, scrotum.

Order I. *RAPTORES.*

Body, very muscular.
Beak, strong, curved, sharp-edged and sharp-pointed, often armed with a lateral tooth; upper mandible the longest. *(Fig 112.)*

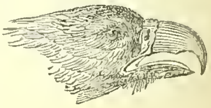


Fig. 112.

* See *Schoepfs*, in *Meckel's Archiv für Physiologie*, B. 12, p. 73.
† Blumenbach more vaguely proposes a Binary arrangement of Birds on the same principle; he divides the class into *Land-Birds* and *Water-Birds*. In *Lawrence's Blumenbach, Comp. Anat.* p. xxxiii.

* Bridgewater Treatise, vol. ii. p. 444.
† This word is proposed by Mr. Kirby as the English for *Raptores*; it is the substantive of *ravenous*, from the verb *to raven*.

Fig. 113.

Legs, robust, short, with three toes before, and one behind; all armed with long, strong, crooked talons. *Fig.* 113.

All the Birds of Prey feed on the flesh of living or recently killed animals. They have a prompt, powerful, and rapid flight. They are monogamous; the female exceeds the male in size. They nidificate in lofty situations and rarely lay more than four eggs: the young are excluded in a blind and feeble state.

The Birds of Prey are either diurnal or nocturnal.

The *Diurnal Raptores* have their eyes directed laterally, and are divided into the following families—*Falconidæ*, Eagles and Hawks; *Vulturidæ*, Vultures; and *Gypogeranidæ*, which includes the Secretary vulture. In the first two divisions the characters of the order are most strongly marked; in the third the legs deviate from the ordinal character and are remarkably elongated, adapting it to an inferior kind of prey, viz. noxious reptiles, serpents, &c.

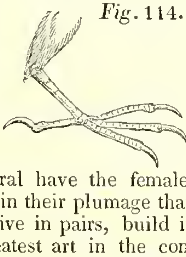
The *Nocturnal Raptores* have the eyes directed forwards, and include the *Strigidæ* or owl-tribe.

Order II. *INSESSORES.*

Legs slender, short, with three toes before and one behind, the two external toes united by a very short membrane.*

The *Perchers* form by far the most numerous order of birds, but are the least easily recognizable by distinctive characters common to the whole group. Their feet, being more especially adapted to the delicate labours of nidification, have neither the webbed structure of those of the *Swimmers*, nor the robust strength and destructive talons which characterise the feet of the *Bird of Rapine*, nor yet the extended toes which enable the *Wader* to walk safely over marshy soils and tread lightly on the floating leaves of aquatic plants; but the toes are slender, flexible, and moderately elongated with long, pointed and slightly curved claws. (*Fig.* 114.)

Fig. 114.

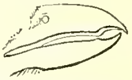


The perchers in general have the females smaller and less brilliant in their plumage than the males; they always live in pairs, build in trees, and display the greatest art in the construction of their nests. The young are excluded in a blind and naked state, and wholly dependent for subsistence during a certain period on parental care. The brain arrives in this order at its greatest proportional size; the organ of voice here attains its utmost complexity, and all the characteristics of the bird, as power of flight, melody of voice, and beauty of plumage are enjoyed in the highest perfection by one or other of the groups of this extensive and varied order.

The beak of the *Inscssores* varies in form according to the nature of their food, which may be small or young birds, carrion, insects, fruit, seeds, vegetable juices, or of a mixed kind. The modifications of the rostrum have therefore afforded convenient characters for the tribes or subdivisions of the order; these are termed, 1, *Dentirostres;* 2, *Conirostres;* 3, *Tenuirostres;* 4, *Fissirostres.*

The *Dentirostres*, (*fig.* 115) characterized by their insect food, and the notch near the extremity of the upper mandible, include the families termed *Laniadæ* or Shrikes; *Merulidæ*, Thrushes; *Sylviadæ*, Warblers; *Pipridæ*, Tits; and *Muscicapidæ*, Fly-catchers.

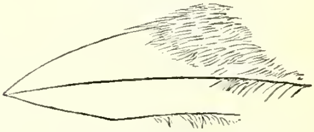
Fig. 115.



Rostrum of a Shrike

The *Conirostres* (*fig.* 116) include the two orders of M. Temminck, termed *Omnivores* and *Granivores;* and are characterized by a strong and conical beak, the margin of which is generally entire; the greater part are omnivorous, the rest granivorous; these latter are the *Hard-billed Birds* of Ray. The families of the tribe are the following: *Sturnidæ*, Starlings; *Corvidæ*, Crows; *Buceridæ*, Hornbills; *Loxiadæ*, Cross-bills; *Fringillidæ*, Finches, Larks.

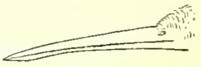
Fig. 116.



Rostrum of a Crow.

The *Tenuirostres* (*fig.* 117) or suctorial birds form, Mr. Vigors observes, "the most interesting group, perhaps, of the animal world. Deriving their subsistence for the most part from the nectar of flowers,* we never fail to associate them in idea with that more beautiful and perfect part of the vegetable creation, with which in their delicacy and fragility of form, their variety and brilliancy of hues, not less than by their extracting their nourishment from vegetable juices, they appear to have so many relations. As the tribe is confined exclusively to the torrid zone and southern hemisphere, the naturalists of our northern latitudes have little opportunity of observing their manners or of inspecting their internal construction."†

Fig. 117.



Rostrum of the Orthorhynchus, or Straight-billed Humming Bird.

* The genus *Ceyx*, Lacép. (*Alcedo tridactyla*, *Pall.*) affords an exception, the inner toe being deficient; and the two other anterior ones being united as in the other Syndactyles, it appears as if there was but one toe in front opposed to one behind.

* In the Humming-Birds which we have dissected, we have found the remains of minute insects in the gizzard.

† We have selected the skeleton of the Humming-bird, one of this tribe, as a striking illustration of the

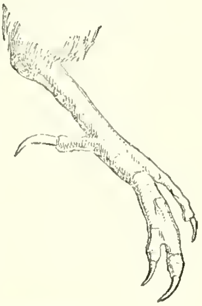
This distinguished ornithologist proposes to divide the *Tenuirostres* into the following families: *Cinnyridæ*, Sugar-eaters; *Trochilidæ*, Humming-birds;—in which families the beak and feet are more remarkable for their tenuity and length: and *Promeropidæ*, Hoopoes; *Meliphagidæ*, Honey-suckers; *Nectariniadæ*, Nectar-birds;—in which the slenderness of the beak and feet is less remarkable.

Fig. 118.

Rostrum of the Caprimulgus.

The *Fissirostres*, (*fig.* 118), like the *Tenuirostres*, are distinguished by a habit of feeding on the wing, but as their food, instead of vegetable juices, consists of living insects, the form of the beak is modified accordingly, and is remarkable for its shortness and the wideness of its gape, especially in the typical families. In these the mode of catching the prey is conformable to their distinguishing characters; they receive it in full flight into the cavity of their mouths, which remain open for that purpose, and where a viscous exudation within and a strong fence of *vibrissæ* on the exterior, assist in securing the victim. The longer-billed *Fissirostres*, on the other hand, seize their food by their bills. The following are the families of the Fissirostral tribe: *Hirundinidæ*, Swallows; *Caprimulgidæ*, Goat-suckers; these are characterized by the short, wide, and weak bill. *Todidæ*, Todies; *Halcyonidæ*, King-fishers; *Meropidæ*, Bee-eaters; these latter families are characterized by their stronger and longer bill, and further differ from the preceding in having the external toe nearly as long as the middle one to which it is united as far as the penultimate joint; they are therefore termed *Syndactyles* by Cuvier. *Fig.* 119 represents the foot of the King-fisher.

Fig. 119.



Order III. *SCANSORES.*

Feet with two toes before and one behind. (*Fig.* 120.) The disposition of the toes which results from the external one being turned back like the thumb, gives the *Scansores* great facility in climbing the branches of trees, but proportionally impedes their progression along level ground.* Their nests are less skilfully constructed than those of the Insessores, and are generally made in the hollows of old trees; one family, indeed, is remarkable for depositing its eggs in the nests of other birds. Their powers of flight are moderate;* their food consists of insects and fruit. The scansorial families are the *Psittacidæ*, Parrots; *Picidæ*, Woodpeckers, Wry-necks; *Cuculidæ*, Cuckoos; *Rhamphastidæ*, Toucans.

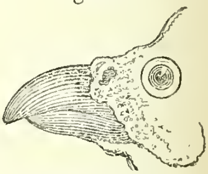
Fig. 120.

Foot of the Woodpecker.

Order IV. *RASORES.*

Upper mandible, vaulted; *nostrils*, pierced in a membranous space at their base, covered by a cartilaginous scale. *Legs*, strong, muscular; three toes before united at their base by a short membrane, and one behind, higher than the rest, furnished with short, blunt, and robust nails, for the purpose of scratching up the food. *Tail-feathers* 14—18.

Fig. 121.



Beak of the Guinea-fowl.

The food of the Scratchers, or gallinaceous birds, being vegetable substances, as grains and seeds, they have a large crop and extremely muscular gizzard. They mostly deposit and hatch their eggs on the ground in a rudely constructed nest of straw. Each male has ordinarily many females, he takes no part in nidification or in rearing the young; and these are generally numerous and able to run about and provide for themselves the moment they quit the shell.

The families of the *Rasores* are the *Columbidæ*, or Dove-tribe; *Craeidæ*, Curassow-birds; *Phasianidæ*, Pheasant, common Fowl; *Tetraonidæ*, Grouse, Partridge.

Order V. *CURSORES.*

Wings very short, not used for flying; *legs* robust; *Sternum* without a keel.

This order includes the *Brevipennes*, which constitute a tribe of Waders (Grallæ) in the Cuvierian system; and form in the system of Mr. Vigors, a family of Rasores under the term *Struthionidæ*. They differ remarkably from one another, both in the form of the beak and feet, and each known species forms the type of either a separate genus or family.

adaptation of the vertebrate skeleton to powers of flight.

* There are peculiar exceptions to the general character in this as in most other orders of birds. Among the *Cuculidæ*, the 'Traveller's Friend,' of South America,' and among the *Psittacidæ*, the 'ground parrots' of New South Wales, are remarkable for their preference of the ground, for progression along which their elongated naked tarsus, and slender toes, of which one of the hind ones can be brought forward to the front row, favourably adapt them.

* The *Trichoglossi* of New Holland afford as remarkable an exception in respect of powers of flight; for instead of the usual short rounded wings of the parrot tribe, they have them elongated and pointed like those of a hawk, and dart through the forests with inconceivable rapidity.

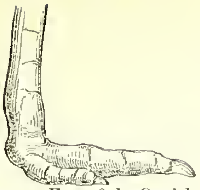


Fig. 122.

Foot of the Ostrich.

The *Coursers* with a *depressed* beak have the longest and strongest legs, and run with remarkable velocity; these include

The Ostrich (*Struthio Camelus*) which has only *two* toes. (*Fig.* 122.)

The Rhea (*Rhea Americana.*), the Cassowary (*Casuarius galeatus.*), the Emeu (*Dromaius ater.*), which have three toes, all turned forward.

Of these four giants of the class the first inhabits the continent of Africa, the second South America, the third Java, and the fourth Australia.

The *Coursers*, with a *compressed* beak, are represented by a single and now extinct genus, the Dodo, (*Didus ineptus*, Linn.)

This bird is known from a description given by one of the early Dutch navigators, and preserved in Clusius (*Exoticorum libri decem descr.* 1605, pp. 99 and 100); by an oil-painting of the same period, copied by Edwards (*Gleanings*, plate 294); from a description and figure in Herbert's *Some Years Travels in Africa, Asia, &c.* 1677; and from the *Historia Naturalis et Medica*, of Jacob Bontius, 1658.

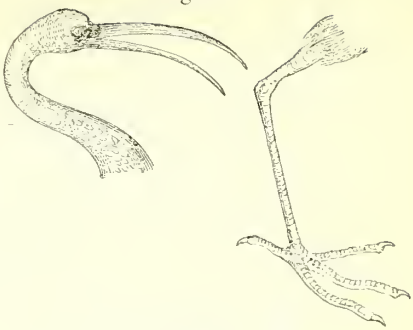
A foot of the Dodo is preserved in the British Museum, and a head in the Ashmolean collection at Oxford. The beak resembles that of the Penguin or Albatross rather than that of a Vulture, to which it has been compared. The foot would resemble that of the Aptenodytes, if it were webbed, which however it is not nor has been. It is very similar to, but proportionally stronger than, the foot of the Curassow. We have examined carefully the foot in the British Museum, and also the head of the Dodo at the Ashmolean Museum, and derived a conviction that they are the remains of a bird *sui generis*.

A third form of beak among the *Brevipennes* or *Cursores* is presented by the *Apteryx Australis*; a bird inhabiting and apparently peculiar to the island of New Zealand. The mandibles are elongated and slender, the upper one is marked on either side by a longitudinal furrow. The toes are, as in the Dodo, four in number; but the fourth, or posterior one, is smaller, being reduced almost to a spur, and the three anterior ones have the lateral skin, notched as in the *Phaleropes*. The wings are shorter than in any other known bird, are quite concealed by the feathers, and terminate in a sharp spine or claw. The feathers are narrow like those of the Cassowary.

Ordo VI. *GRALLATORES.*

Legs with the tibia, and especially the metatarsus very long, stretched out behind in flight; the distal end of the tibia unfeathered; *toes* elongated, straight. *Wings* long. *Body* slender; neck and beak long.

Fig. 123.



Head and leg of the Ibis.

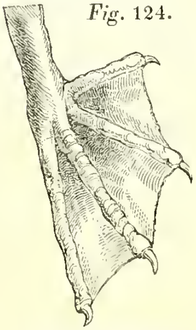
The Waders,—or *Grallæ*, as they were termed by Linnæus from being raised on their long legs, as on stilts,—frequent for the most part the banks of lakes and rivers, marshes, and the shores of estuaries, and derive their food, some exclusively from the waters, feeding on small fishes, aquatic mollusks, worms, small reptiles, and insects, as well as their spawn, while others are of more terrestrial habits and food. Of the latter kind are the *Gruidæ*, or Stork tribe, which are chiefly vegetable feeders, and resemble the land birds in their bill and feet; the former being more obtuse than in the typical waders, and the latter shorter. Then follow the *Ardeidæ*, or Heron tribe; the *Scolopacidæ*, Snipe, Woodcock; the *Rallidæ*, Rail, Coot; and the *Charadriadæ*, Plover, Sanderling, &c.

The Waders are remarkable for their power of preserving a motionless position upon one leg for a considerable length of time; the mechanism by which this is effected will be afterwards described. During flight they stretch out their long legs behind to counterbalance their long neck, and the tail is always extremely short, its function as a rudder being transferred to the legs. They mostly make or choose their nests on the ground, and the young are enabled to run about as soon as hatched, excepting in those Waders which live in pairs.

Ordo VII. *NATATORES.*

Body closely covered with feathers, and coated with a thick down next the skin. *Legs* short, placed behind the point of equilibrium. *Toes* united by a membrane or web, which is sometimes divided.

Fig. 124.



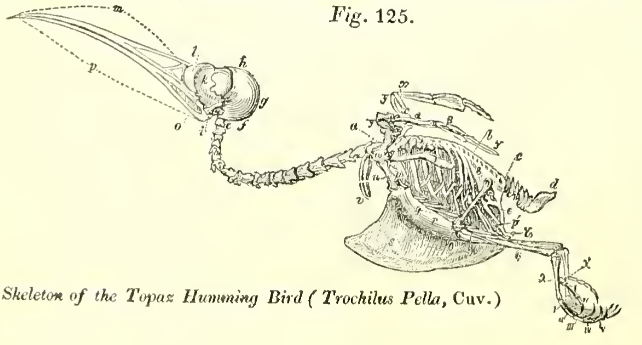
Foot of the Pelican.

The Swimmers, or *Palmipedes*, are of all the orders of birds the most easily recognizable by the structure and position of their oar-like feet: this peculiarity which occasions an awkward gait on land, is extremely favourable to those birds 'whose business is in the great waters.' Their body is boat-shaped, and generally elongated, as is also their neck. Their dense plumage is oiled and lubricated by the secretion of the coccygeal glands, which are remarkably developed for that purpose. In general the males have many females, and in harmony with this speciality the young are hatched in a condition which renders the cooperation of both parents for their support unnecessary, being able to take to the water and swim about in search of food the instant that they are liberated from the egg-coverings. The families of Swimmers are the *Anatidæ*, Swan, Goose, Duck; *Colymbidæ*, Divers; *Alcadæ*, Auks; *Pelecanidæ*, Pelican, Cormorant, Gannet; *Laridæ*, Gulls.

1. *Osteology.*—The skeleton of Birds is remarkable for the rapidity of its development and the light and elegant mechanism displayed in the adaptation of its several parts. The osseous substance is compact, and exhibits more of the laminated and less of the fibrous texture than in the other vertebrate classes. This is more especially the case in those parts of the skeleton which are permeated by the air. The bones which present this singular modification have a greater proportion of the phosphate of lime in their composition than is found in the osseous system of the mammalia, and they are whiter than the bones of any other animal. In the bones where the medulla is not displaced or dessicated by the extension of the air-cells into their interior, the colour is of a duller white. In the Silk or Negro-fowl of the Cape de Verd Islands (*Gallus Morio*, Temminck) the periosteal covering of the bones is of a dark brown, and in some parts almost black colour; but this ought to be regarded as a peculiarity of the cellular rather than of the osseous texture, which does not differ in colour from that of other birds; indeed the thin aponeurosis covering the lateral tendons of the gizzard of the Silk-fowl is observed to have the same dark hue as the membrane which invests the bones.

Although in the disposition of the parts of the osseous system of birds the plan which pervades the vertebrate type of structure is nowhere absolutely violated, yet the variations from that plan required by the peculiar exigencies of the class are of the most striking and interesting kind. We shall successively consider the relations of these modifications to the powers and habits of the bird as they present themselves in the vertebral axis, in the bones of the head and thorax, and in those of the anterior and posterior extremities.

Fig. 125.



Skeleton of the Topaz Humming Bird (Trochilus Pella, Cuv.)

The vertebral axis or spine is divisible into a *cervical* (*fig.* 125, *a*), *dorsal* (*b*), *sacral* (*c*), and *caudal* (*d*) region; the vertebræ immediately succeeding those which bear ribs have a lateral anchylosis with the *iliac* bones, and therefore there is no part of the spine which possesses the characters of the *lumbar* vertebræ of mammalia and reptiles.

The vertebræ are the first parts of the osseous system which make their appearance in the development of the embryo, and they are of all parts of the skeleton the most constant in their existence and general characters.

The *dorsal* or costal vertebræ in birds rarely form more than a fourth part of the entire vertebral column, and in some of the long-necked *Grallatores*, as the Stork, form only an eighth part of the spine; they have not been observed to be fewer than six nor more than eleven in number throughout the class: the latter obtains in the Swans (*Cygnus canorus et olor*) and Sheldrake; the most common numbers are seven or eight.

The dorsal vertebræ are short, as compared with the cervical: they appear broad when viewed superiorly, in consequence of the great development of the transverse processes; but their bodies are much compressed in the lateral direction, so as to be reduced almost to the form of vertical laminæ towards the sacral region. This is especially observable in the Penguins (*Aptenodytes, Catarrhactes*); but in the Ostrich the bodies of the dorsal vertebræ retain their breadth throughout.

The bodies are not united by intervertebral substances, but by capsular ligaments and synovial membranes; the anterior articular cartilaginous surface is convex in the vertical direction, and concave in the transverse; the posterior surface is the reverse. The Penguins, however, present a remarkable exception to this rule. The posterior surface of the third dorsal vertebra is uniformly concave, to which the opposed end of the fourth vertebra presents a corresponding convexity: the ball and socket joint is continued between the several vertebræ to the last dorsal, which is anchylosed to the sacrum. This is an interesting affinity to the *Reptilia*, in addition to numerous others displayed in the construction of these singular birds. In most birds the bodies of some of the middle dorsal vertebræ are anchylosed together; and in general those which are nearest the sacrum. In the Flamingo we have observed this anchylosis extending from the second to the fifth dorsal vertebra. In the Sparrow-hawk the second, third, fourth, and fifth dorsal vertebræ are consolidated into one piece, while the sixth enjoys considerable lateral motion both upon the fifth and seventh, which last is anchylosed to the sacrum; so that the body can be rapidly and extensively inflected towards either side during the pursuit of prey. This structure and its uses were first pointed out by Mr. H. Earle.

The bodies of the anterior dorsal vertebræ send down processes from their inferior or ventral surfaces for the advantageous origin of the *recti antici majores* muscles of the neck. These processes differ from the inferior spines of the tail in not being perforated for the passage of an artery. This part of the spine is further strengthened by the extension of osseous splints from the transverse processes, which unite those of contiguous vertebræ together, and also by the anchylosis of the spinous processes. But where a similar necessity for the fixation of the trunk does not exist, as in the Struthious birds and Penguins, which cannot fly, all the dorsal vertebræ are moveable upon each other. When it is considered that the head, posterior extremities, and viscera are suspended in flight from this central portion of the trunk, and that it has almost exclusively to sustain the shock of the violent contractions of the principal muscles of the wings, the necessity for the mechanism consolidating the dorsal vertebræ will be readily appreciated.

Immobility and strength are still more obviously required in that part of the spine by which the weight of a horizontal body is to be transferred to a single pair of extremities articulated to the trunk behind the centre of gravity. The anchylosis of the bodies of the vertebræ, which already begins to appear in the last dorsal, is, therefore, continued through all the sacral vertebræ as far as the caudal region; and this consolidated mass (*b* to *c*) is united laterally to the iliac bones. Hence it is always difficult to determine the number of vertebræ of which it is composed. We have made sections of the sacrums of many different birds with a view to determine this fact, and have generally found the number greater than that which is indicated in the tables of Cuvier. Thus the Stork has twelve, instead of eleven sacral vertebræ; the Coot thirteen, instead of seven; the Kingfisher eleven, instead of eight: while the Ostrich, on the other hand, has but seventeen, instead of twenty bones of the sacrum. The bodies of the sacral vertebræ are broad, but shallow, and towards the tail the floor of the vertebral canal is formed by a mere lamina of bone: the canal is remarkably dilated in this part of the spine for the enlargement of the cord which gives off the nerves to the posterior extremity. It is a curious fact that the roots of these nerves pass out of the osseous canal by separate orifices, the ganglion on the posterior root and the union of the two being external to the spine. The aspect of all these orifices is lateral, in the intervals of the transverse processes of the different vertebræ, which are not united together as in the mammalia. The first four or five sacral vertebræ give off two sets of transverse processes, one ventral, the other dorsal; the ventral ones are wanting in the succeeding four, and then suddenly reappear to abut against the symphysis of the ilium and ischium, and are so continued double to the end. The spinous processes which are principally developed from the anterior sacral vertebræ, give off from their extremities lateral expansions, which anchylose with the iliac bones, and form an osseous roof, arching over and concealing the transverse processes.

The *coccygeal* vertebræ of birds, though never prolonged into a conspicuous caudal appendage, are in general moveable upon each other, and are frequently nine in number. With the exception of the last, they are broad and short and perforated for the lodgement of the spinal marrow. With the exception of the last also they have spines on both the dorsal and ventral aspects; and the anterior vertebræ have also transverse processes. The last caudal vertebra (*d*, *fig.* 125) is so singularly shaped, that were it found alone in a fossil state it would hardly be recognized as a bone of the spine. It has no medullary canal and no processes; but is compressed laterally and terminates above and often also below in a sharp edge; its posterior extremity is obtuse. It supports the coccygeal oil-gland, and affords a firm basis to the tail feathers, which, from their use in guiding the motions of the bird through the air, Linnæus termed the *rectrices*.*

In the Toucan the three last caudal vertebræ are anchylosed together; the six anterior ones are articulated by ball and socket joints, the ball and the socket being most distinct in the two last of these joints; that between the sixth and seventh vertebræ is provided with a capsule and synovial fluid, the others have a yielding ligamentous mode of connexion. The spinous processes of these vertebræ, both superior and inferior, are of moderate size, but smallest in the sixth, where the greatest degree of motion takes place; the transverse processes on the contrary are large and broad so as almost to preclude lateral motion. We have given a more particular description of these vertebræ because of the singular movements observable in the tail of the Toucan; it can be inflected dorsad till the superior spines of the vertebræ are brought in contact with the sacrum; and in the performance of this motion the lateral muscles, which at first tend rather to oppose the elevators, become, at a certain point of inflection dorsad of the centre of motion, elevators themselves, and thus combining with the elevators jerk the tail upon the back; it is thus that the tail turns as if on a hinge operated upon by a spring.

As the prehensile functions of the hand are transferred to the beak, so those of the arm are performed by the neck of the bird; this portion of the spine is therefore composed of numerous, elongated, and freely moveable vertebræ, and is never so short or so rigid but that it can be made to apply the beak to the coccygeal oil-gland, and to every part of the body for the purpose of oiling and cleansing the plumage. In birds that seek their food in

* In the tail-less variety of the common Fowl the coccygeal vertebræ have degenerated into a single unshapely knotty process.

water it is in general remarkably elongated, whether they support themselves on the surface by means of short and strong natatory feet, as in the Swan, or wade into rivers and marshes on elevated stilts, as in the Crane, &c.

The articular surfaces of the bodies of the *cervical* vertebræ, like those of the dorsal series above mentioned, are concave in one direction and convex in the other, so as to lock into each other, and in such a manner that the superior vertebræ move more freely forwards, the middle ones backwards, while the inferior ones again bend forwards; producing the ordinary sigmoid curve observable in the neck of the bird.

This mechanism is most readily seen in the long-necked waders which live on fish and seize their prey by darting the bill with sudden velocity into the water. In the common Heron, for example, *(Ardea cinerea)* the head can be bent forward on the atlas or first vertebra, the first upon the second in the same direction, and so on to the sixth, between which and the fifth the forward inflection is the greatest; while in the opposite direction these vertebræ can only be brought into a straight line. From the sixth cervical vertebra to the thirteenth the neck can only be bent backwards; while in the opposite direction it is also arrested at a straight line. From the fourteenth to the eighteenth the articular surfaces again allow of the forward inflection, but also limit the opposite motion to the straight line.

Two transverse processes are ordinarily continued from the anterior part of the bodies of the cervical vertebræ: the inter-space of these is filled up externally to the vertebral artery by a rudimentary styliform rib, which is separated in the young bird, but afterwards anchylosed, and directed backwards parallel to the body of the vertebræ. These processes give attachment to numerous muscles of the neck, and being, with the transverse processes, more strongly developed in the rapacious birds, give a greater breadth to the cervical region in that order.

The superior spinous processes are but feebly developed; they are most distinct on the vertebræ at the two extremities of the cervical portion of the spine. Inferior spinous processes are also found on the vertebræ at the commencement and termination of the neck, but are wanting in a great proportion of the intermediate cervical vertebræ.

The atlas is a simple ring. In general it is articulated with the occipital tubercle by a single concave facet on the body; but in the Penguin and Ostrich there are two other facets, continuous with the middle one, but corresponding with the anterior articulating processes of the rest of the vertebræ and applied to the condyloid portions of the occipital bone, while the middle facet is articulated to the basilar portion as in other birds. The body of the dentata is joined to the atlas by a single synovial capsule, its odontoid process is tied down by a strong transverse ligament stretched above it, and by a longitudinal one extending from its extremity to the posterior part of the occipital condyle. In the articulations of the bodies of the remaining cervical vertebræ a moveable inter-articular cartilage is found inclosed between reduplications of the synovial membrane, as in the joint of the lower jaw in mammalia. The articulations of the oblique processes have no peculiarities worthy of notice.

A remarkable difference is found in the diameter of the spinal canal contained in the cervical vertebræ. If, *e. g.* the sixth cervical vertebra of a Stork be sawed down vertically, the antero-posterior diameter is greatest in the middle, least at the ends; but if it be sawed lengthwise horizontally, the transverse diameter is the reverse, being narrowest at the centre and widest at the ends. In the Ostrich, the Swan, and many other birds the spinal canal is widened in every direction at the extremities of the vertebræ; and on the dorsal or posterior aspect of the spine, the canal remains open for some extent in the intervals of the vertebræ, the cord being there protected only by membrane and the elastic ligaments which connect the roots of the spinous processes together. The final purpose of this structure has been ably illustrated by Mr. Earle in the Philosophical Transactions, (1822, p. 276.) where he shews that it is adapted to prevent a compression of the spinal cord during the varied and extensive inflections of the neck.

The vertebræ of the different regions of the spine bear a different proportion to each other in respect to number among birds, from what we observe in the mammalia and reptilia. The cervical portion in this class is generally composed of a much greater number of vertebræ than any of the other divisions of the spine; in this respect the fossil reptilian genus called *Plesiosaurus* alone resembles the bird. This singular animal was an inhabitant of the waters, and it is interesting to observe that the peculiarity which distinguishes it, viz. the great length of neck, is chiefly characteristic of the *Aves aquaticæ* of Nitzsch. In the *Grallatores* the length of the neck is determined by the height of the legs: in the *Natatores* it is necessary for the purpose of obtaining their food while swimming the waters. The dorsal vertebræ are usually less numerous than in mammalia. The caudal vertebræ are subject to few variations; they never project in the form of a tail, but are most numerous in those birds which make the greatest use of the tail-feathers, as in the Swallows, to direct their rapid flight, and in the Woodpeckers, where they serve as a prop or climbing pole.

The following table, which, with some corrections, is extracted from Cuvier's Leçons d'Anatomie Comparée, exhibits the variety that exists with respect to the number of vertebræ in different species of birds.

Table of the number of vertebræ in birds.

Order. RAPTORES	*Vertebræ.*			
Species.	Cervical.	Dorsal.	Sacral.	Caudal.
Vulture	13	7	11	7
Eagle	13	8	11	8
Osprey	14	8	11	7
Sparrow-hawk ..	11	8	11	8

Species.	Cervical.	Dorsal.	Sacral.	Caudal.
Buzzard	11	7	10	8
Kite	12	8	11	8
Great Horned Owl	13	7	12	8
Hawk-owl	11	8	11	8
Order. INSESSORES.				
Flycatcher	10	8	10	8
Black-bird	11	8	10	7
Tanager	10	8	9	8
Crow	13	8	13	7
Magpie	13	8	13	8
Jay	12	7	11	8
Starling	10	8	10	9
Gross-beak	10	7	12	7
Bull-finch	10	6	11	6
Sparrow	9	9	10	7
Goldfinch	11	8	11	8
Titmouse	11	8	11	7
Lark	11	9	10	7
Redbreast	10	8	10	8
Swallow	11	8	11	9
Night-jar	11	8	11	8
Humming-bird	14	9	10	8
Hoopoe	12	7	8	7
King-fisher	12	7	11	7
Order. SCANSORES.				
Woodpecker	12	8	10	9
Toucan (Ariel)	12	8	12	9*
Parrot	11	9	11	8
Order. RASORES.				
Pigeon	13	7	13	7
Peacock	14	7	12	8
Pheasant	13	7	15	5
Turkey	15	7	10	5
Crested Curassow	15	8	10	7
Order. CURSORES.				
Ostrich	18	10	17	9
Cassowary	16	10	19	7
Rhea	14	9	?†	?
Emeu	19	9	19	9
Order. GRALLATORES.				
Heron	18	7	10	7
Stork	19	7	12	8
Crane	19	9	12	7
Argala	14	7	13	7
Spoon-bill	17	7	14	8
Avoset	14	9	10	8
Plover	15	8	10	7
Lapwing	14	8	10	7
Wood-cock	18	7	13	8
Curlew	13	8	10	8
Oyster-catcher	12	9	15	7
Rail	13	8	13	8
Coot	15	10	13	8
Jacana	14	8	13	7
Flamingo	18	7	12	7

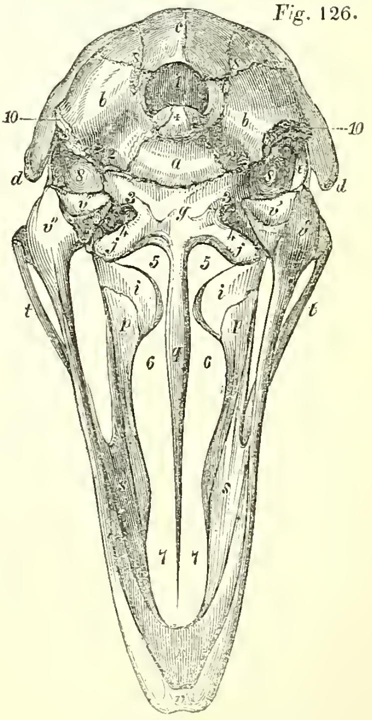
* Cuvier says "plus de 7 :" we have ascertained the above number in a dissection of a recent specimen of this singular genus (*Rhamphastos Ariel*, Vigors) Zool. Proceedings, vol. 11. p. 42.

† This part of the spine is singularly modified and interrupted by a natural atrophy of many of the vertebræ.

Species.	Cervical.	Dorsal.	Sacral.	Caudal.
Order. NATATORES.				
Pelican	16	7	14	7
Cormorant	16	9	14	8
Tern	14	8	10	8
Gull	12	8	11	8
Petrel	14	9	13	9
Catarrhactes	13	9	13	8
Swan	23	11	14	8
Goose	15	10	14	7
Barnacle	18	10	14	9
Duck	14	8	15	8
Sheldrake	16	11	11	9
Scoter	15	9	14	7
Merganser	15	8	13	7
Grebe	14	10	13	7

The skull in all the Vertebrated Classes is composed of a considerable number of osseous pieces, which, in the Mammalia, unite in definite numbers and proportions, so as to form the bones termed *occipital*, *temporal*, *sphenoidal*, &c. In the cold-blooded Vertebrata the component parts of these bones generally remain separated throughout life, giving an appearance of great complexity to the skull, and occasioning much difficulty in tracing their correspondence with the cranial bones of the higher classes. Equal difficulty is experienced in determining the component parts of the head in Birds, but from a very different cause. In the cold-blooded Crocodile, and Fish, this difficulty is caused by the tardiness of ossification, which prevents the coalition of the several elements of the cranial bones into their determinate groups; while, in Birds, the

Fig. 126.



Skull of a young Ostrich.

energetic respiratory and circulating functions occasion so rapid an evolution of the osseous system, that the bones of the cranium become at an early period anchylosed into one piece, with a total obliteration of the original harmoniæ; it is necessary, therefore, to examine the skull of the Bird at an early period of existence, and to compare it with the fœtal condition of the skull of the Mammal, when it will be found to be ossified from analogous centres, which, in their expansion and subsequent union, obey the same laws of, as it were, elective attraction.

The *occipital bone* is originally composed of four pieces: the *basilar*, below, (*a*, *fig.* 126,) the two *condyloid*, laterally, (*b*, *b*,) and the expanded *spinous* process, or supra-occipital piece above (*c*). These fulfil the usual functions of the occipital bone, protecting the cerebellum and medulla oblongata, and forming the medium of connection between the cranial and cervical vertebræ.

The head is articulated to the spine by means of a single hemispherical tubercle (*a*, *fig.* 126,) which plays in a corresponding cavity of the atlas. In most birds the tubercle is formed exclusively by the basilar piece of the occipital bone, but in the Ostrich and Penguin the condyloid portions also contribute to its formation, which is an approximation to the structure of the occipital condyle in the Chelonian reptiles. In all birds, however, the articulation is such as to allow of a much greater extent and freedom of motion to the head than exists in the Mammalia.

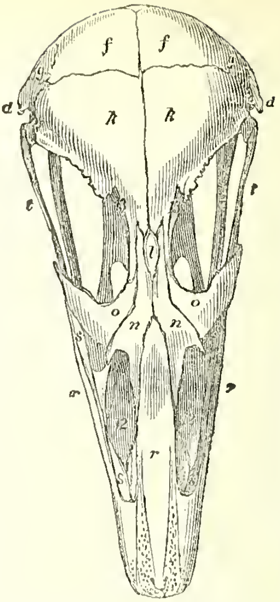
The *temporal bone* consists of the *petrous* portion, the *squamous* portion, (*d*, *d*, *fig.* 126, 127) and the *tympanic* bone, or os quadratum (*e*.) The petrous bone includes the complex parts of the internal ear, and is soon anchylosed to the condyloid portions of the occipital bone, which fulfil the functions of the mastoid processes. The squamous, or, as it may be termed, the zygomatic portion of the temporal bone (*d*) remains for a longer time separate; it forms the lateral boundary of the cranial cavity, as in quadrupeds, and the tympanic element is moveably articulated to its inferior part.

The *parietal bones* (*f*, *f*, *fig.* 127) retain their separated condition till after the union of the occipital pieces, they then unite and protect the posterior part of the cerebral hemispheres.

The *sphenoid bone* is composed of a *basilar* portion, (*g*, *fig.* 126,) two *orbital* plates, (*h*, *fig.* 127,) forming the floor and part of the septum of the orbits, and which rapidly anchylose with the preceding; two *cranial* portions, or alæ majores, (*g*, *fig.* 127, 128,) which remain longer separate, and form the posterior part of the orbits, and two *pterygoid* portions ('interarticular' or 'omoid' bones), (*i*, *i*, *fig.* 126,) which, in birds, abut against the tympanic or quadrate bones. The great alæ of the sphenoid join the parietal, and separate the temporal from the frontal bones.

The *frontal bone* (*k*, *fig.* 127) continues for a longer period than the parietal to be separated into two lateral halves by the continuation of the sagittal suture through its whole length.

Fig. 127.



Skull of a young Ostrich.

The ant-orbital processes (13, *fig.* 127) are elongated and pointed, extending forwards to join the lachrymal bones, (*o*, *o*, *fig.* 127,) considerably beyond the origins of the nasal bones, and are separated from each other by these and by a process of the ethmoid bone. The post-orbital processes are most developed in the Parrots and Maccaws, in the latter of which they join the lachrymal bones, and complete the bony circumference of the orbits, (*fig.* 128.) In the Emeu they remain for a long time distinct bones, as in the reptiles. The frontal bone thus forms the whole of the superior, and, more or less, of the outer boundary of the orbits, and protects the anterior part of the cerebrum. It supports the horn-like prominences which are seen upon the heads of the Cassowary, Pintado, and Curassow, the bony bases of which commence by distinct ossifications.*

A small part of the *ethmoidal* bone (*l*, *fig.* 127) is seen, in the Ostrich, on the exterior of the cranium lodged between the ant-orbital processes and nasal bones (*n*, *n*.) The ethmoid separates, as usual, the orbits from the cavity of the nose, and forms a great part of the inter-orbital septum where this exists, as in the parrots, (*m*, *fig.* 128.)

In the mature bird the whole of the preceding bones, with the exception of the tympanic elements of the temporal bone, are usually found anchylosed into one piece.

The internal surface of the cranium exhibits a well-marked transverse ridge, which divides the cavity into two principal depressions. In the anterior division the hemispheres of

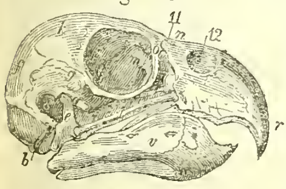
* 'A most remarkable sexual difference appears in the skull of the *crested Hens*: in these the frontal portion of the cranium is dilated into an immense cavity, on which the crest of feathers is placed. This degeneracy of the formative impulse, which is propagated to the offspring, is quite unparalleled in the whole animal kingdom: I have lately examined several heads of such hens in a fresh state, and have found that this peculiar dilatation of the cranium is filled by the hemispheres of the cerebrum, and is separated from the posterior part which holds the cerebellum, as in the common hen, by an intermediate contracted portion.'—*Lawrence's Blumenbach's Comp. Anat.* p. 61.

the cerebrum are lodged, the rest of the brain is contained in the posterior division. The relative proportion of these divisions varies in the different orders; in the *Insessores* and *Accipitres* the anterior superior depression is the largest; in the *Rasores*, the posterior inferior depression equals, and in some species, exceeds the former in size. The orbits form two slight projections in the anterior fossa of the cranium, which is partially divided longitudinally by a ridge corresponding to the interspace of the cerebral hemispheres. This is developed in the Gallinaceous birds into a thin falciform osseous crest, which is especially remarkable in the Partridge, Turkey, and Capercailzie. It is also well developed in the Parrot tribe. The *sella turcica* in all birds is a deep round cell, lodging the pituitary gland, as in the Mammalia.

The foramen magnum (1, *fig.* 126) is formed, as usual, by the union of the four pieces of the occipital bone: its size is considerable, having relation to the mobility of the cranium upon the spine. The foramen lacerum posterius (2, 2, *fig.* 126) is situated immediately below the membrana tympani (8, 8, *fig.* 126.) There is no fissure analogous to the foramen lacerum medius. The carotid foramina (3, 3, *fig.* 126) are transversely oblong, and situated on the body of the sphenoid; the same bone, in the Ostrich, is perforated immediately anterior to the carotid canal by the Eustachian tube, (4, 4.) The posterior palatine foramina are wide spaces, (5, 5,) separated from each other by the vomer (*q*, *fig.* 126). Anterior to these, in the base of the skull, are seen the still wider posterior apertures of the nostrils (6, 6). In the inside of the cranium the internal auditory foramina are distinctly seen. The foramen lacerum anterius is divided into several distinct foramina. The optic foramina, on the contrary, are closely approximated, and frequently blended into one. The olfactory nerves escape each by a single foramen, and are continued to the nose either along a deep groove on the upper part of the orbital septum, or, as in the Toucan, pass through a complete osseous canal.

The bones of the face correspond in number and relative position with those of the Mammalia, but differ considerably in their forms and proportions; they bear most resemblance to the facial bones of the Rodentia. They are always moveably connected with the bones of the cranium, and retain much longer than these their separate condition.

Fig. 128.



Skull of a Parrot.

The *nasal bones* (*n*, *n*, *fig.* 127, 128) are a large and elongated pair, extending from the inner side of the ant-orbital processes of the frontal to the outer side of the ascending processes of the intermaxillary bones, expanding as they advance forwards, and giving off from their outer sides a process which curves downwards to join the superior maxillary bone, to which it has erroneously been considered to belong. The nasal bones soon anchylose with the frontal, ethmoidal, inter-maxillary, and superior maxillary bones.

The *lachrymal* or *ungueal bones* (*o*, *o*, *fig.* 127, 128, *l*, *fig.* 125) are also of considerable proportionate size. They are more exposed than in mammalia, and are usually moveably articulated by their mesial or anterior edge to a varying number of the bones of the skull. These are commonly the frontal, nasal, and malar bones; but in the ostrich the lachrymal articulate with the palatine bones; in the Parrot they extend backwards beneath the orbit to the post-orbitals, and thus complete the bony circumference of that cavity, while in the Owls they do not at all articulate with the frontal bone. They are smallest in the *Rasores* and *Natatores*, and attain their greatest development in the diurnal *Raptores*. In these the separated supra-orbital bones give additional protection to the eye, over which they form, in conjunction with the lachrymal, the projecting arch so characteristic of the physiognomy of the bird of prey.

The *palatine bones* (*p*, *p*, *fig.* 126,) are of great proportional size: each is of an elongated, slender, depressed figure, becoming narrower anteriorly, forming the posterior part of the palatine arch, and completing with the vomer the boundary of the posterior nostrils. In the *Raptores* the palatine bones are united together only by a small part of their anterior extremities. In the Owls the posterior extremities are widely separated from each other. In the *Insessores* they are not united together in any part of their extent, except in the Grossbeak, (*Loxia Coccothraustes*,) at the anterior extremity. In this bird and in the Parrots, the palatine bones have not a horizontal but a vertical position, contrary to what they are in most other birds. They are least developed in the *Rasores*.

The *vomer* (*q*, *fig.* 126) is rapidly anchylosed in the Ostrich with the sphenoid, appearing as a long, moderately compressed, pointed process, extending forward from the spine of the sphenoid in the interval of the palatine bones, and dividing the posterior aperture of the nose into two lateral halves. In most other birds it remains distinct from the spine of the sphenoid, as it is also in the ostrich at a very early period.

The *intermaxillary bone* (*m*, *fig.* 125, *r*, *r*, *fig.* 126, 127, 128) determines the form, and constitutes the greater part, of the upper mandible. It consequently presents considerable variety in its figure and proportions, and also in its mode of articulation, in different birds; but in every species it is of considerable size. When completely ossified, which it is at a very early period, the intermaxillary bone consists of three processes which diverge from, or unite to form, the extremity of the upper mandible: the superior mesial process or nasal plate is lamellate, depressed or flattened horizontally, extends backwards between and above the lower ends of the nasal bones, and becoming wedged, as it were, between their upper ends, is articulated in general by an anchylosis to them and the ethmoid bone. This union, however, always allows of a certain elastic or yielding motion to pressure from below. In the Parrots, where the upper mandible is an important instrument in their climbing habits, the nasal plate of the intermaxillary bone is joined to the cranium by a ligamentous substance (11, *fig.* 128). The two lateral or mandibular processes (*r*, *r*, *fig.* 127) of the intermaxillary bones diverge and extend backwards, external and superior to the superior maxillary bones; and, in the Ostrich, they articulate with the anterior extremities of the malar or zygomatic bones. Throughout their whole course the mandibular processes are in close contact with, and soon become anchylosed to the superior maxillary bones. The ossification of the intermaxillary bone obeys the ordinary law of centripetal development. The lateral moieties are still separate in the chick at the conclusion of incubation; and in the duckling they do not anchylose until six weeks after that period. The union commences at the anterior extremity, while at the opposite or cranial end of the nasal process, traces of the original separation may frequently be observed in the full-grown bird; these are very conspicuous in the Gulls, (*Laridæ*).

The *superior maxillary bones* (*s*, *s*, *fig.* 126, 127) are very seldom united together in birds. They are comparatively of small size. Each may be said to commence mesiad of the origin of the mandibular processes of the intermaxillary bone; it then expands as it proceeds backwards, and, opposite the anterior end of the palatine bone, divides into two processes. The mesial or palatine process extends along the outside of the palatine bone, and soon becomes anchylosed to it; the external or malar process is articulated obliquely to the under part of the anterior moiety of the zygomatic bone. At the origin of this process a small projection meets the descending process of the nasal bone. In most Gallinaceous birds, the body, or part anterior to the palatine and zygomatic processes, is wanting; but in the common fowl it extends towards the mesial line, and unites with the vomer, so as to divide the palatal fissure into an anterior and posterior cavity. In the Ostrich, where the body of the upper maxillary extends forwards to the symphysis of the intermaxillary bone, a process is also given off at the origins of the palatine and zygomatic bones, which passes inwards to the vomer, and completes, in the adult, the boundary of the anterior palatal fissure.

The movement of the bony framework of the upper mandible resulting from the union of the intermaxillary, superior maxillary, and palatal bones, is immediately effected by the elongated *malar* or *zygomatic bone*, (*o*, *fig.* 125, *t*, *t*, *fig.* 126, 127, 128,) which transfers to the zygomatic process of the superior maxillary the movements of the tympanic bone, being so placed as to form the medium of communication between these parts. It extends in a straight line from one to the other, this being the form best adapted to resist the pressure upon its two extremities. With the superior maxillary bone it is soon anchylosed, but with the tympanic bone it is in most Birds articulated by a moveable ball and socket-joint, the articular surfaces being connected by a fibro-cartilaginous substance; in the *Caprimulgi*, however, it is anchylosed at both extremities. The malar bone is commonly of a compressed or vertically flattened form, but sometimes, as in the Ostrich, it is cylindrical. It is originally composed of two pieces placed in a parallel line, one above the other; the superior being pointed at both extremities, and much smaller than the other.

The *tympanic*, pedicellate, or quadrate bone (*i*, *fig.* 125, *e*, *fig.* 126, 128,) is never anchylosed with the other elements of the temporal bone, but is freely moveable as in most of the cold-blooded ovipara; and it is interesting to observe that in the rodent quadrupeds, which exhibit many other affinities to birds, the tympanic element remains for a long period a detached bone, but is situated altogether posterior to the maxillary articulation. In birds, where the base of the cranium is remarkably shortened in the antero-posterior diameter, the tympanic bone is, as it were, thrust forward and wedged in between the inferior maxillary bone and the zygomatic process of the temporal, thus intercepting, and articulating with, both the lower jaw and cheek-bones. The *membrana tympani* continues, however, to be attached by about half its circumference to the posterior part of the os quadratum, and for the remainder of its extent to the occipital and sphenoidal bones.

The upper end of the tympanic bone is articulated by two distinct transverse condyles with the zygomatic portion of the temporal bone; below these it is contracted, and then expands as it descends, giving off a strong process from the middle of its anterior surface, which projects into the orbit, then a smaller process from its posterior surface extending backwards, and lastly, sending off at its lower extremity an external process for the malar bone, and an internal one for the pterygoid, between which processes are two oblique oblong convexities for the articulation of the lower jaw.

Having an immediate connection with the motions of the whole beak, it necessarily presents varieties of form in different birds, without, however, losing the characteristic figure which has been described. By whatever cause the tympanic bone is carried forwards, whether by the action of the *pterygoid muscles* inserted into its orbitar process, or by the pressure of the lower jaw upon its inferior surface, that motion is communicated to the pterygoid and malar bones, which transfer it, the one to the palatine, the other to the superior maxillary bones, and thus the upper mandible is elevated at the same time that the lower one is depressed. The elasticity of the union of the nasal process of the intermaxillary bone with the cranium restores the upper jaw on the cessation of the pressure from below, to the position from which the movement of the tympanic bones had displaced it.

These movements are freely allowed in most birds from the nature of the articulation of the tympanic bone; but in the Struthious birds they are more restrained, from the connection of the bone with the descending zygomatic process of the temporal bone; the extent of this attachment is greatest in the Emeu, where it almost produces a complete fixation of the tympanic bone.

The *inferior maxillary bone (p, fig.* 125, *v, figs.* 126, 128,) is originally composed of twelve distinct pieces, each lateral moiety being made up of six. The anterior *symphyseal* or dental portion of each ramus first unites with its fellow at the symphysis; the two portions which form the *condyle (v, fig.* 126) next anchylose; the *angular (v, fig.* 126), *supra-angular* and *opercular*, or *splenial* pieces are consolidated at a later period. The anterior extremities of the angular and supra-angular pieces are wedged into corresponding grooves of the symphyseal element; and the opercular portion is extended like a splint along the inner side of the gomphosis, by which the preceding portions are united.

The traces of the original separation of these bones long remain in the semi-aquatic and aquatic birds (*Grallatores* and *Natatores*), which, as the lowest of the class, manifest their affinity in this respect to the cold-blooded Ovipara, where this complex structure of the lower jaw continues throughout life.

As the lower jaw, thus constituted, forms with the upper jaw the principal organ of prehension in birds, it presents many variations of form and magnitude, which immediately relate to, and are consequently indicative of their mode of life, food, &c. These general modifications will be treated of in relation to the digestive function, but some of the less conspicuous characters of the lower jaw may be more appropriately considered in this place.

The rami are in general completely anchylosed at the symphysis, the extent of the united portions varying considerably in different birds, but occupying in most cases only a small proportion of the jaw. In the Pelicans the rami are united by the mere extremities, appearing as if bent upon each other at the symphysis, and supporting the dilatable sac which fills up the intermediate space, like the hoop of the fisherman's landing-net. The symphysis is also of very small extent in most other Palmipeds. It is small in the *Rasores* and *Cursores*. In the Storks and Cranes it extends along a third part of the entire jaw. In the Flamingo, where the anterior part of the jaw is bent down at an obtuse angle, nearly half of the rami are united. In the Skimmers (*Rhyncops*), Hornbills, and Toucans, two-thirds. In the Curlew the two rami are in apposition for two-thirds of their anterior extent, but are not anchylosed, and form, in this respect, the only known exception to the rule.

In diurnal Birds of Prey, in many of the Parrot-tribe, in the Herons and Swans, each ramus of the lower jaw forms an entire bony plate. In the rest of the class a membranous unossified space is left at the place of union of the symphyseal with the angular, supra-angular, and splenial elements. This deficiency is of a longitudinal form, and is always situated behind the middle of the ramus. In the Bustards, Woodcocks, Curlews, Gulls, Skimmers, Guillemots, Petrels, and Penguins, there is a second foramen, of a rounder figure, posterior to the preceding, and resulting from a defective union of the angular, supra-angular, and condyloid pieces. In the Cassowary this space is subdivided into several small foramina. In the Emeu (*Dromaius*) and Ostrich (*Struthio*) there is a single small foramen at the corresponding part.

At the posterior part of each ramus the following processes are developed in various degrees in different birds. The suprangular piece ascends in a greater or less degree in the form of a thin lamina with a gently rounded outline, representing the *coronoid process.* From the inner side of the condyloid piece there extends a more marked process, which may be called the *internal angular;* and from the posterior part of the ramus a third process is continued, which may be termed the *posterior angular process.*

The coronoid process is most developed in the Parrots, Gulls, Herons, and Cross-bills (*Loxia*), in some of which, as the *Loxia coccothraustes, cardinalis,* and *pulverulentus,* the lower jaw presents the following peculiarity. A large sesamoid bone of a triangular form, but rounded and transverse, with the base directed outwards and the apex inwards, is situated at the posterior and internal aspect of the articular ligament of the lower jaw. It completes the maxillary articulation posteriorly, and corresponds by its anterior articular surface to the posterior part of the outer condyle. The articular surface of the lower jaw of the Parrots is a simple narrow longitudinal furrow, open at the two extremities. That of the Toucans is almost equally simple, but of a rounder figure. In most other birds the articular surface is divided into two distinct portions, of which the internal is an oblique concavity, the external also oblique, but terminating in a convex eminence behind.

In the Rasorial birds the coronoid process is feebly developed, but the internal and angular processes are of large size. The latter is very remarkable in the great Cock of the woods, (*Tetrao urogallus,*) where it extends upwards and backwards in a curved form for the extent of an inch, affording attachment to the powerful muscles required to produce the wide expansion of the mandibles necessary to seize the large fir-cones which constitute its food. In the lamellirostral Palmipedes not only are the internal, and the posterior angular processes of large size, but there are also two eminences for muscular attachment on the outer side of each ramus anterior to the articular surface. In the Gulls an oblique ridge is continued from a single eminence similarly situated.

The articular capsule of the lower jaw is strengthened by ligamentous fibres arising from the lower extremity of the tympanic bone, and passing backwards to be inserted into the outer side of the internal angular process. This ligament assumes a fibro-cartilaginous structure at its anterior part: it is attenuated internally, and is situated between the two bones in the outer part of the capsular ligament. At the posterior part of the joint a strong fibrous band extends from the end of the mastoid process to the internal angular process of the lower jaw, so as to restrain the forward movement of the jaw.

The skull presents fewer varieties of form in birds than in any other class of vertebrate animals. With the exception of a few species, in which the beak assumes what may almost be termed a monstrous development, it has the form of a pretty regular five-sided pyramid, of which the occiput forms the base, and the anterior extremity of the beak the apex.

The posterior facet or base of the pyramid is formed by the upper and larger portion of the occiput, together with part of the temporal bones. It is the smallest facet of the head, and is larger in the transverse than the vertical diameter. It presents the vertical prominence corresponding to the narrow cerebellum, which is separated by a venous foramen and furrow (8, *fig.* 126) from a broad muscular depression on either side; below these are the large occipital foramen, (1, *fig.* 126); the hemispheric tubercle, which unites the head to the atlas; and on either side of this tubercle a smaller muscular depression, separated by a transverse ridge from the larger one above, and perforated by the pneumogastric and hypoglossal nerves; these depressions are bounded laterally by the mastoid processes. (10, 10, *fig.* 126.)

The inferior facet or base of the skull joins the posterior and lateral facets almost at a right angle. It is bounded anteriorly and at the sides by the lower jaw, which, on account of the compressed form and divarication of the rami, scarcely intercepts any part of the view of this very complicated surface. The occipital condyle, with the muscular depressions on either side and the mastoid processes, may be considered in some, and more especially in the Struthious birds, as forming part of the base of the skull. Anterior to the basilar portion of the occiput comes the body of the sphenoid, which in the *Struthionidæ* sends outwards and forwards two rounded processes *(j j, fig.* 126) to abut against the flattened pterygoid bones. Between the origins of these, and anchylosed to the spine of the sphenoid, the vomer extends forwards to a distance varying in different birds. The tympanic bones are seen on either side of the body of the sphenoid, and external to these the zygomatic processes of the temporal; the space circumscribed by these bones, with the mastoid processes behind, forms the expanded external passage of the ear, which is closed in the recent state by the large convex *membrana tympani*, (8, 8, *fig.* 126.) Anterior to the tympanic bones the pterygoid processes *(i i, fig.* 126) extend forwards and inwards to join the palatine bones; which are then continued forwards to the superior maxillary, leaving between them the large posterior nasal fissure divided longitudinally by the vomer. These fissures are commonly continuous with the anterior palatal fissure, (7, 7, *fig.* 126,) but in the full grown Struthious and some Gallinaceous birds, the palatine and maxillary bones unite with the vomer and separate the two fissures, thus increasing the bony floor of the nasal cavities. External to the rami of the lower jaw, the malar or zygomatic bones may in general be seen converging from the tympanic to the superior maxillary bones, the elongated triangular space between these bones and the pterygoid and palatine leads directly from below into the large orbits.

The two lateral facets present posteriorly the tympanic or auditory cavity, (8, *fig.* 128,) anterior to which is the tympanic bone, with the malar and inferior maxillary bones extending forwards from its lower extremity. Above the tympanic bone is the zygomatic process of the temporal, *(d, fig.* 128,) arching over it in the Struthious and Psittaceous birds, as if to effect its normal connection with the malar bone. Between the zygomatic and post-orbital processes is the crotaphyte depression, (*g*, *fig.* 128,) always well-marked, but bounded by ridges more or less developed in different birds. At the lower part of this depression may be perceived the large foramen common to the superior and inferior maxillary divisions of the trifacial nerve. Then come the spacious rounded orbits, bounded above by the supra-orbital lamella, behind by the sphenoid and frontal expansions, which form, at the same time, the anterior walls of the cranium; separated from each other, but always more or less incompletely, by the thin sphenoidal and ethmoidal plates, the deficiencies of which are supplied in the recent state by aponeurotic membranes, and defended anteriorly by the largely developed lachrymal bones and the ethmoidal alæ, between which there are always present apertures varying in size. The pterygoid and palatine bones, with the styliform malar bone, form a very incomplete floor of the orbit.

Anterior to the orbits the sides of the skull become gradually narrower to the end of the beak; between the lachrymal and the superior maxillary bones a large triangular or rounded space is left, (11, *fig.* 128,) which conducts to the nasal cavity. A second vacancy occurs, anterior to this, bounded by the nasal, superior maxillary, and intermaxillary bones, forming the osseous boundary of the wide external nostrils. (12, *figs.* 127, 128.)

The superior surface of the cranium is generally convex in relation to and indicative of the development of the brain; it is rounded posteriorly, where it is generally widest. Here on each side is seen the temporal depression: the interorbital space in the Gulls, Petrels, Albatrosses, Penguins, and other sea-birds, presents also two depressions, scarcely less marked, of a semilunar form, the convexities meeting in the mesial line, and lodging a gland, whose secretion is carried into the nose to lubricate the pituitary membrane. Slight traces of these glandular depressions may be seen at 13, *fig.* 127, in the Ostrich. In other birds the interorbital space is moderately concave or flattened. Anterior to this part the cranium in the Parrot presents the moveable junction of the upper mandible, but in other birds a continued osseous surface converges more or less gradually to the end of the beak, only interrupted by the anterior orifices of the nasal cavity.

The skull in the *Raptores*, especially in the nocturnal division, is short, broad, and high, in proportion to its length, and the cranium is large compared with the face. The posterior facet is convex, and remarkably extended upwards and laterally, and is continued insensibly at an obtuse angle with the upper surface. The occipital foramen is almost horizontal. The temporal fossæ are not very deep, and do not meet above at the middle line. The cerebral convexities are not strongly marked; the frontal region is flat. A longitudinal furrow extends along the whole upper surface of the cranium, and is especially remarkable in the Owls. The cranium and face are separated by a sudden contraction. The orbits are very complete, on account of the development and complete junction of the frontal, ethmoidal, ungueal, and palatine boundaries.

The cranium of the *Warblers* presents a more regular sphericity, but the interorbital space is very concave. The anterior parietes of the orbits are large and very complete from the size of the lachrymal bone and of the transverse lamina of the ethmoid; the internal and posterior bony parietes are, on the other hand, remarkably defective; the optic foramina are indeed commonly blended into one, and continuous with the larger fissures above.

The distinctive characters of the skull of the *Scansores* are the most remarkable, especially in the Parrots and Toucans. In the former the upper surface of the cranium is flattened or slightly convex, and greatly extended in breadth between the orbits. These cavities are very complete; and the nasal inlets on the sides of the skull are much limited in size by the extent of ossification. However, the breadth of the posterior part of the base of the cranium and the large size of the pterygoid bones occasion a very considerable interval between these and the body of the sphenoid.

In the Toucans the cranium slightly increases in breadth to the anterior part where it is joined to the enormous bill. Its superior surface presents an equable convexity. The temporal fossæ, like those of the parrots, are small, and wholly confined to the lateral aspects of the cranium. The posterior surface, which is absolutely concave in the Maccaws, from the backward extension of the mastoid processes, is slightly convex in the Toucans, where it is separated from the upper surface by a regularly arched ridge. The cerebellic prominence extends over the occipital foramen, the plane of which inclines forwards and downwards from the horizontal line at an angle of 45°. The circumference of the orbit is uninclosed by bone at the posterior part, the postorbital processes of the frontal not being developed as in the parrots. The zygomatic process of the temporal, with the ligament extending between it and the malar bone, forms here the posterior boundary of the orbit. The septum of the orbits is very incomplete. The ungueo-maxillary fissure and the external nasal apertures are very small, and situated on nearly the same perpendicular line, the nostrils open on the posterior part of the upper mandible, and the remainder of the lateral facet is, therefore, a smooth entire osseous surface formed by the thin parietes of the dilated cellular mandibles.

In the Hornbills the skull presents the same characters as in the Toucans, with the exception of that extraordinary species the Helmeted Hornbill (*Buceros Galeatus.*) In this bird the whole outer surface of the skull is sculptured with irregular furrows and risings, a character which it presents in no other bird, and which can only be compared to the surface of the skull in the Crocodiles. The posterior surface is concave, and separated by a strongly developed ridge from the temporal furrows, which almost meet at the vertex. The bony rim of the orbit is completed by the extension of the zygomatic process of the temporal to that of the malar bone, which, however, are not anchylosed, but joined by a ligamentous union. The bony septum of the orbits is complete, and formed by two strong plates, separated by an intermediate cellular diploë, except at the posterior part. The optic foramen is directed transversely outwards. In all the Hornbills the malar bone is moveably connected with the maxillary as well as the tympanic bones, as in other birds.

In the Wood-peckers the cranium is rounded, the temporal fossæ shallow, the internal wall or septum of the orbits incomplete, but the anterior boundary is well developed. The posterior facet of the cranium is raised. The superior surface is traversed by a wide furrow extending longitudinally forwards, generally to the right, but sometimes also to the left, as far as the lachrymal bone. It is in this furrow that the elongated cornua of the os hyoides are lodged, which relate to a peculiar mechanism hereafter to be described. In some of the larger species of Wood-pecker, as the *Picus major*, L. the cranial furrow is more symmetrical. In the Humming-birds it is double, the hyoidean furrows being separated at first by the cerebellic protuberance, and afterwards by a mesial longitudinal ridge.

The skull in the *Rasorial* birds is narrow, but slightly raised, and without ridges. In the Capercailzie (*Tetrao Urogallus*) it is almost square, flattened on the posterior and superior surfaces, and impressed with a considerable longitudinal furrow anteriorly. The orbit is very incomplete, the anterior parietes being almost entirely wanting, and the ungueo-maxillary vacancy being consequently continuous with the orbit. In the Bustards the posterior boundary of the ungueo-maxillary fissure is complete, but in other respects the cranium resembles that of the *Rasores*.

The skull is remarkable for its length in the majority of the *Waders*. In the Herons and Bitterns the occipital region is low, and inclines from below upwards and forwards; it is separated from the upper and lateral regions by a well developed, sharp, lambdoidal crest; and it is divided into two lateral moieties by a slight longitudinal ridge. The temporal fossæ are deeper and wider than in any of the preceding orders; and they now extend upwards, as in many of the carnivorous mammalia, to the sagittal line, along which an osseous crest is developed to extend the surface of attachment of the temporal muscles. The cranium is expanded, anteriorly to the above fossæ, as if to allow of a compensating space for the development of the cerebral hemispheres, the interspace of which is indicated by a deep longitudinal furrow, almost peculiar to these genera of birds. The roof of the orbits is expanded laterally, which gives great breadth to this part of the head, but the posterior orbital walls are very imperfect, and the internal walls or septum almost wholly wanting. The optic foramina are blended with each other and with the smaller foramina, which in other birds represent the *foramen lacerum orbitale*. The anterior boundary of the orbits is also very imperfectly completed, the ungueo-naso-maxillary and anterior nasal fissures are not remarkable for their extent.

Woodcocks, Snipes, Curlews, and Lapwings, resemble Herons in their defective bony orbits; but they want the extended superior parietes of those cavities, and differ much in the almost spherical form of the cranium, which is smooth and devoid of the muscular ridges characteristic of the fish-feeding *Grallæ*. In this order the intermaxillary bones present some of their most eccentric forms. They are narrow, elongated, and curved downwards in the Ibises and Curlews; bent upwards in the contrary direction in the Avosets; extended in a straight line in the Snipes; singularly widened, and hollowed out in the Boat-bill (*Cancroma*); widened, flattened, and dilated at the extremity in the Spoon-bill; thickened, rounded, and bent downwards at an obtuse angle in the Flamingo.

Among the *Natatores*, the sea-birds, as the Divers, (*Colymbus*), Grebes, (*Podiceps*), and Cormorants (*Carbo*), are characterized for the defective condition of the bony orbits, and of the anterior parietes of the cranium; the septum of the orbits is almost entirely wanting; in place of the posterior parietes there are two lacunæ leading directly into the cranial cavity, one superior, of large size, and one inferior, smaller; they are, in general, separated by a narrow osseous bar, but in the Coulterneb, (*Fratercula arctica*) this is also wanting, so that all the anterior cerebral nerves escape by a common opening. But in this species it must be observed, that the vertical lamina of the æthmoid is ossified at its posterior part. In the Petrels and Albatrosses, the internal and posterior walls of the orbits are more complete. In the *Diomedea exulans* the optic foramina are separated both from each other, and from the neighbouring outlet. The occipital region is low, and divided into a superior and an inferior facet, the latter being concave from side to side. The plane of the occipital foramen is almost vertical. The occipital or lambdoidal crista is well-marked, and the temporal fossæ nearly approximate in the middle line. In these sea-birds and in the Gulls, the lateral lacunæ in the bony parietes of the face are very considerable.

A most remarkable characteristic of the cranium of both the Brachypterous and Macropterous Sea-birds is the presence of the two deep, elongated, semilunar glandular depressions before mentioned, extending along the roof the orbits. In the aquatic birds which frequent the marshes and fresh waters, as the *Anatidæ* or *Lamellirostres*, these glandular pits are wanting, or very feebly marked, as in the Swans. They are, however, again met with of large size, though shallow, in the Curlews (*Numenius*) and Avosets (*Recurvirostra*); and are also found, though of smaller size, in the Flamingo.

Of the thorax.—In every part of the skeleton of Birds, we may observe that there is a close adherence to the oviparous modification of the vertebrate type of structure. This is manifested in the forms and connections of the several vertebræ, and of the cranial bones. It is no less conspicuous in the structure of the thorax.

The ribs are apparently in moderate number, but when their analogues are closely sought for, they are found to extend, as in the Crocodile, along the greater part of the cervical region. In fact the small styliform processes which point backwards from the lateral projections on the anterior parts of the bodies of these vertebræ remain separate after the true elements of the vertebræ have coalesced. In an Ostrich which had attained half its growth, we have found these spurious ribs still moveable. They anchylose, however, with the transverse processes in general long before the growth of the individual is completed, excepting towards the caudal extremity of the cervical region, where comparative anatomists, from this circumstance, have always found a difficulty in determining the commencement of the dorsal vertebræ. If the moveable ribs had commenced, as in Mammalia, by extending to the sternum, the determination of their number would have been easy; but they begin, sometimes by a gradual and at others by a sudden elongation,* opposite the furculum, from which point, either one, or two, as in the Humming-bird, (see *p*, *fig*. 125,) terminate by extremities imbedded in muscle, and unconnected with any corresponding portion extending from the sternum.

Meckel considers the true number of ribs in the Diurnal *Raptores* to be nine pairs, of the Nocturnal eight; in the *Insessores* seven or eight; in the *Scansores* nine, except the Cuckoo, which has seven or eight; in the

* This is remarkably the case in the Wood-Grouse (*Tetrao Urogallus*), where the penultimate and last cervical ribs, instead of gradually enlarging, diminish in size, so that the determination of the first thoracic rib is easy.

Rasores seven or eight; in the *Struthiones* the number of ribs varies; in the Ostrich (*Struthio*) we find ten pairs, of which the 3d, 4th, 5th, and 6th, are articulated with the sternum; in the Nandou (*Rhea*) there are nine pairs, of which only the 3d, 4th, 5th, and 6th, are completed by sternal portions; in the Emeu (*Dromaius*) there are nine pairs, the 3d, 4th, 5th, 6th, and 7th, being joined to the sternum; in the Cassowary (*Casuarius*) there are ten pairs, and of these the 4th, 5th, 6th, 7th, 8th, and 9th, have sternal portions. The last pair of ribs in *Struthio* and *Rhea* are extremely short, and abut against the expanded iliac bones. Among the *Grallatores* we find seven pairs of ribs in the Herons (*Ardea*), and Gigantic Stork (*Ciconia Argula*) while the Cranes (*Grus*) have nine, and the Coots and Water-Hens have ten pairs. In the *Natatores*, which vary so much in their locomotive powers and habits of life, we find a corresponding variety in the number of ribs; in the Willock (*Uria troile*) there are twelve pairs, and in the Guillemots and allied sea-birds eleven; in the Swans eleven; in the Penguins nine, of which six are articulated with the sternum.

The true ribs are not joined to the sternum by elastic cartilages, but by straight osseous portions, called sternal ribs, (*q*, *fig*. 125, *h*, *fig*. 129,) which are moveably connected at both their extremities. These are the centres upon which the respiratory motions hinge; the angle between the vertebral and sternal ribs, and between these and the sternum becoming more open in inspiration, and the contrary when the sternum is approximated to the dorsal region in expiration.

As the ribs are traced backwards, their vertebral extremities are seen to become gradually double or bifurcated from the increasing development of the part answering to the cervix and head of the rib in Mammalia. The spurious cervical ribs may be plainly seen to be articulated, like the posterior spurious ribs of the Cetacea, by the tubercle only; and, as they increase in length in the proximity of the thorax, the head of the rib is then seen to be thrown downwards to join a distinct tubercle on the side of the body of the vertebra close to its anterior margin, but without encroaching on the intervertebral space. The comparative immobility of the dorsal vertebræ allows of this mode of articulation; but it is an interesting circumstance that in the Ostrich, where the costal vertebræ preserve their mobility, the heads of the ribs, at least of those of the anterior ones, evidently pass forwards to the intervertebral space. The tubercle of the rib has thus less the character of a subordinate process than in the ribs of mammalia; it is supported on a pedicle, and is articulated by a simple synovial joint with the transverse process of the corresponding vertebra. The ribs, below the union of the two articular processes, are thick and strong, but they gradually become flattened, and increase in breadth as they descend towards the sternum. This is especially remarkable in the second, third, and fourth ribs of the Woodpecker. The dorsal ribs are not only connected together by muscles and aponeurotic membranes, but cooperate with the anchylosed dorsal vertebræ, in giving stability to the trunk by means of small osseous splints, detached from the posterior margin of each true rib, and directed backwards and upwards to the next in succession, to both of which they are united by means of oblique fibrous ligaments. In birds of powerful flight these connecting pieces are, as might be expected, most developed. In the *Raptores* they extend beyond and overlap the succeeding posterior rib, and in this order they are anchylosed.

In some of the Struthious birds, as the Ostrich and Rhea, they exist from the third to the fifth rib, while in the Emeu and Cassowary there are only rudimentary traces of them. In the Penguins these accessory processes are remarkable for their breadth, but they are never anchylosed to the ribs, and consequently are apt to be lost if care be not taken in preparing the skeleton.

The sternal ribs (*h*, *h*, *fig*. 129) are of a less flattened form than the vertebral; they increase in length as they are situated further back; their costal extremity is simply rounded, while their sternal extremity is extended transversely and divided into two smooth surfaces moveably articulated by two synovial capsules with corresponding cavities in the sides of the sternum. The first sternal rib is, however, joined by fibro-cartilaginous substance only, while one or two of the posterior pieces are anchylosed with the rib immediately preceding them, and do not reach the sternum. In the Ostrich the last rib abuts against the ilium, to which it is anchylosed.

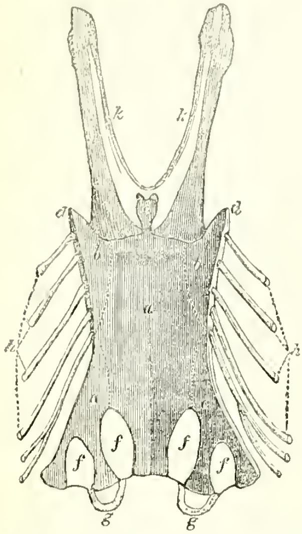
In the Peacock, Pintado, and common Fowl, the vertebral and sternal portions of the last pair of ribs are unconnected with each other; the latter thus representing the ossified tendinous intersections of the rectus abdominis muscle, as in the Crocodile. This analogy is still more striking in the Herons, Storks, and Curlews, and in many of the *Natatores*, in which the sternal portions alone exist, and are remarkably elongated.

The part of the skeleton which has undergone the most remarkable modifications in relation to the powers and functions of the anterior extremities is the *sternum*, (*r*, *s*, *fig*. 125 and 129,) which gives origin to their principal muscles. It is so developed, both in length and breadth, as to extend over the whole of the anterior or ventral aspect of the thoracic and of a great part of the abdominal cavities, reaching in some birds of great powers of flight even to the pubic bones, so as to require removal before the abdominal cavity can be examined.

In order to afford origin to the accumulated fasciculi of the pectoral muscles, which otherwise would become blended together over the middle of the sternum, an osseous crest (*s*, *fig*. 125, *a*, *fig*. 130) is extended downwards, analogous to the cranial crest which intervenes to the temporal muscles in the carnivorous mammalia; and as this crest indicates in these the powers of the jaw, so the sternal keel bespeaks the strength of the anterior extremity in the bird.

Besides the difference of form and development of the mesial crest or keel, the extended sternum presents many other varieties in the different orders and families of birds. A zoological arrangement of the class has even been founded on the modifications of this characteristic and important part of the skeleton. In every species the sternum is more or less

Fig. 129.



Sternum, coracoids, and clavicles of a Woodpecker.

quadrilateral, more or less convex outwardly, and each of its margins affords distinctive characters. The anterior margin presents two grooves (*b*, *b*, *figs.* 129, 130) extending along the greater part of either side, and affording a secure articulation to the coracoid bones; and in many birds it sends forward a process from the middle part where the two grooves meet, as in the Woodpecker and Penguin (*e*, *fig.* 129). This mesial process we shall term the *manubrial process*, since it is analogous to that which extends from the manubrium or first sternal bone of the seal, mole, &c.

The lateral margins are straight and excavated anteriorly, to a greater or less extent, for the lodgement of the sternal ribs. In some birds a process (*d*, *figs.* 129, 130) is given off at each angle of the union of the lateral with the anterior margin· as this process seems to supply the sternal portions of the anterior floating ribs, it may be termed the *costal process*.

The posterior margin is most varied in its contour, and is in general interrupted by fissures, (*f*, *f*, *figs.* 129, 130.) which are always symmetrical in their position, but vary in number and depth, so that this margin is sometimes represented by the extremities of three or five long processes.

In the *Diurnal Raptores* the sternum is a large elongated parallelogram, convex both in the direction of its length and breadth, but especially in the latter sense. The manubrial process is thick, the contour of the keel convex, and its margin extended laterally.

In the Eagles and Secretary-bird the sternum is entire, but in the Vultures and Hawks it is pierced on either side by a small round aperture situated near the posterior margin. Ossification sometimes extends along the aponeurotic membrane stretched over this aperture so as to divide it into two, as has been observed in the Buzzard; or so as to obliterate it on one side only, as seen by Meckel in the Kite.

In the *Nocturnal Raptores* the sternum is short, convex as in the preceding tribe, but weaker: there is no manubrial process. The keel is less developed, its margin less convex, and not thickened. The posterior margin is concave and presents two fissures, separated by a middle process, except in the common Barn Owl (*Strix flammea*) where it is wanting, and a large but shallow fissure is found instead.

The greater part of the ***Insessorial Birds*** are characterized by the following form of sternum. It is large, a little longer than broad, and pinched in, as it were, at the sides, just behind the costal margin. The keel is prominent and convex along its inferior margin; its anterior margin is slightly excavated, and terminates below in a slightly projecting angle. The manubrial process is compressed, prominent, and curved upwards; the costal processes are moderately developed. The posterior margin presents a single deep fissure on either side, and a single lateral process, the extremity of which is constantly dilated. The lateral margins are slightly excavated.

In the *Corvidæ* the keel is more excavated at its anterior margin; the manubrial process is stronger, and is bifurcated at the extremity; the posterior fissures are shallower; the angular processes directed outwardly and not dilated at the extremity. In the Swallows (*Hirundo*) the sternum is large and the keel greatly developed; there are two posterior fissures, but they are still shallower than in the Crows; the angular processes are not dilated at the extremities. In the Swifts (*Cypselus*) the sternum is entire, and corresponds in its proportional magnitude with the superior length and power of wing which characterizes this genus. The manubrial process is wanting, but the costal processes are moderately long and pointed.

In the Humming-birds, which sustain themselves on the wing during the greater part of the day, and hover above the plant while extracting its juices, the sternum (*r*, *s*, *fig.* 125,) is still further developed as compared with the body; it approaches to a triangular form, expanding posteriorly, where the margin is entire, and rounded. The depth of the keel exceeds that of the entire breadth of the sternum. The coracoid depressions are deep and approximated; the manubrial process is small, but evident, and directed upwards; the costal processes are also present, but of small size.

In the Creepers (*Certhia*) and Hoopoes

(*Upupa*), the sternum again becomes diminished in size, and presents the two fissures on the posterior margin; the keel is moderately developed; the manubrial process is produced anteriorly; it is of a compressed form in the Hoopoe, but thick, and bifurcate in the Creepers; there are no costal processes.

In the Wood-peckers the keel of the sternum is more feebly developed, its inferior margin is straight, and the angle formed by its union with the anterior margin truncate. The manubrial process enlarges as it advances forwards, and is bifurcate at the extremity. The costal processes are also long, and curved forwards; the posterior margin has four deep notches (*ff*, *fig.* 129).

In the Trogons, Rollers (*Coracias*), Kingfishers, Bee-eaters (*Merops*), Toucans, and Touracos, the sternum is characterized by two fissures on either side at the posterior margin.

In the Parrot tribe the sternum again singularly resembles in its integrity that of the higher *Raptores*, being in some species simply perforated on either side near the posterior margin, and in others wholly ossified. It is, however, narrower in proportion to its breadth. The keel is well developed, its inferior margin concave, its anterior one describing a sigmoid flexure; their angle of union rounded. The costal depressions occupy almost the entire lateral margins of the sternum. The manubrial process is slightly developed, trihedral, and truncate at the extremity.

In the Pigeons, which unite the *Insessorial* to the *Gallinaceous* order, the sternum is narrow, but the keel is deep, with its inferior border convex, and the anterior one curved forwards, thin and trenchant; the manubrial process is strong and bifurcated; the costal processes short. The posterior margin is cleft by two fissures on either side of the mesial plane, the lateral and superior fissures being the deepest; the mesial ones are occasionally converted into a foramen. The costal surface of the lateral margin is, as in the Gallinaceous birds, of very little extent. In the Crown Pigeon the superior fissures are so deep and wide as to convert the rest of the lateral margin into a mere flattened process, which is dilated at the extremity.

In the true *Rasores* the four posterior fissures of the sternum are so deep and wide from its defective ossification, as to give to the lateral parts of this bone, or hypo-sternal elements, the appearance of a bifurcated process extending backwards from the costal margin. The mesial fissures are here the deepest, extending as far as the anterior border of the keel. This part is short, straight, or very slightly convex inferiorly; concave at the anterior margin, which is formed by two ridges which converge to it from the anterior margin of the sternum. This margin is convex laterally, and largely excavated for the coracoid bones; the depressions are continuous with each other, and the compressed manubrial process, arching over the canal, converts it into a foramen. The costal processes are prolonged upwards and forwards; the posterior lateral processes pass backwards exterior to the ribs, supporting them in the Capercailzie, like a semi-hoop; these processes are dilated at their extremities.

In the *Grallatores* or Waders the sternum corresponds in size to the shortness of the thoracic-abdominal cavity. In the *Ardeidæ* the grooves of the anterior surface pass reciprocally beyond the middle line, increasing the surface of attachment for the expanded lower and posterior extremities of the coracoid bone. In most of the genera the posterior margin presents a single fissure on either side; these in the Storks and Herons are wider at the commencement than at the termination. In the Plovers, Woodcocks, Avosets, and Oyster-catchers, it occupies the whole breadth of the sternum. In the Curlews, Ibises, and Spoonbills, there are two fissures on either side. In the Coots and Water-hens the single fissures on either side of the keel are long and narrow, and the lateral portions of the sternum extend backwards beyond the middle, and become larger towards their extremities.

Among the *Natatores*, the Albatrosses, Petrels, Pelicans, and Cormorants present a strong wide convex sternum, similar to the Storks and Herons; the keel is moderately developed, but prolonged anteriorly; the posterior margin presents a single slight fissure on either side. In the Penguins, these fissures are of considerable extent (*f*, *f*, *fig.* 130,); but the keel of the sternum is well developed, even in the Aptenodytes; its inferior border is straight. In the Gulls and Sea-swallows the sternum is of large size, wide, and convex; it presents posteriorly two small and shallow fissures on either side, of which the lateral and superior are sometimes converted into foramina. The keel extends along the whole of the sternum, but is of moderate depth, and convex inferiorly.

In the *Anatidæ* or *Lamellirostral* tribe the sternum is thin, but of large size, very convex transversely, and much elongated. The keel is of moderate depth, and of a triangular form, its inferior margin being straight; there is only one fissure on either side posteriorly.*

In the Divers (*Colymbus*) the portion of sternum intermediate to the two fissures is prolonged beyond the lateral pieces, and the manubrial process is strongly developed, and of a rounded form; the whole bone is remarkable for its length. In the Grebes the sternum is characterized by a third mesial fissure of a chevron figure intermediate to the two ordinary fissures of the posterior margin.

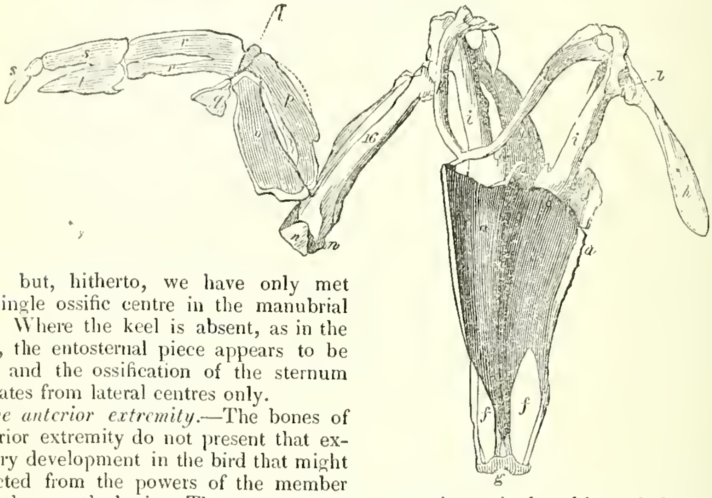
The sternum of the Cursorial Birds presents few affinities of structure to that of the rest of the class, resembling rather the expanded plastron or abdominal plate of the Tortoises. It has neither a keel, nor manubrial, nor costal processes, and may be compared to a square shield. It is most convex in the Rhea, and least so in the Ostrich;

* The modifications of the sternum in relation to the folded trachea will be treated of in the article on the Organs of Voice.

in the latter there may be observed slight indications of the two ordinary posterior fissures.

The ossification of the perfect sternum of the Bird commences from five centres, — a middle one which supports the keel, termed by by Geoffroy St. Hilaire the *entosternal (a, fig.* 129); two anterior lateral pieces, the *hyosternals (b, b, fig.* 129), and two posterior lateral pieces, the *hyposternals (c c, fig.* 129). The posterior cartilaginous appendages he terms *xiphi-sternals (g g, fig.* 129, 130). If to these be added the two portions or *episternals* of which he supposes the manubrial process to be composed, then *nine* elements may be reckoned to enter into the composition of the sternum; but, hitherto, we have only met with a single ossific centre in the manubrial process. Where the keel is absent, as in the *Cursores*, the entosternal piece appears to be wanting, and the ossification of the sternum here radiates from lateral centres only.

Fig. 130.



Of the anterior extremity.—The bones of the anterior extremity do not present that extraordinary development in the bird that might be expected from the powers of the member of which they are the basis. The great expanse of the wing is here gained at the expense of the epidermoid system, and not exclusively produced by folds of the skin requiring elongated bones to support them, as in the Bats, Dragons, and Flying-fish. The wing-bones are, however, both in their forms and modes of articulation, highly characteristic of the powers and application of the muscular apparatus requisite for their due actions in flight.

The bones of the shoulder consist, on each side, of a *scapula (h, fig.* 130), a *coracoid* bone *(i)*, and a *clavicle (k)*,—the clavicles being mostly anchylosed together at their mesial extremities, constitute a single bone, which, from its peculiar form, is termed the *os furcatorium* or *furculum*. In the Ostrich the two clavicles are distinct from each other, but are severally anchylosed with the coracoid and scapula, so as to form one bone on either side. In almost every other species of bird the scapula, coracoid, and clavicle remain separate or moveably articulated throughout life. In the American Ostrich *(Rhea)* and Java Cassowary *(Casuarius)* the acromial element or clavicle is anchylosed with, or rather is a continuous ossification from, the scapula; but the coracoid bone is free; and this condition is worthy of notice as it is precisely that which the bones of the shoulder present in the Chelonian Reptiles; where the coracoid element has been erroneously regarded as the clavicle, in consequence of its being moveably articulated with the scapular piece. In the Emeu *(Dromaius)* it is interesting to observe that the clavicle commences by a distinct ossification, and long continues separate; it does not reach the sternum, but holds the same relative situation as the continuous acromial or clavicular process of the scapula in the other Struthious birds.

The *scapula (t, fig.* 125, *h, fig.* 130) is most readily recognised as such, in the Penguins of the genus *Aptenodytes*, where it is broader and flatter than in any other bird: in these, however, it is of considerable length in proportion to its breadth, and does not exhibit any trace of spinous process. In the rest of the class it is a simple narrow elongated bony lamina, increasing in thickness as it approaches the joint of the shoulder; there it is extended in the transverse direction, forming externally the posterior half of the glenoid cavity, and being internally more or less produced to meet the clavicle, while it is strongly attached in the remainder of its anterior surface to the coracoid bone. The position of the scapula is longitudinal, being extended backwards from the shoulder, parallel to the vertebral column, towards which, however, it, in general, presents a slight convexity. In birds of strong powers of flight, as in the Swift, *(Cypselus,)* it reaches to the last rib, while in the Emeu, on the contrary, it extends over two ribs only. In the Humming-bird *(Trochilus)* its posterior third is bent downwards at a slight angle.

The *coracoid (u, fig.* 125, *i, figs.* 129, 130), or posterior clavicle, is always the strongest of the bones composing the scapular arch: its expanded extremity is securely lodged below in the transverse groove at the anterior part of the sternum, from which it extends upwards, outwards, and forwards, but frequently almost in the vertical position to the shoulder-joint, where it is united at an acute angle with the scapula and clavicle. It thus forms the main support to the wing, and the great point of resistance to the humeri during the downward stroke of this aerial oar. The superior or humeral end of this bone is commonly bifurcate; the outer process is the strongest, and completes the glenoid cavity anteriorly, (*l*, *fig.* 130,) above which it rises, to a greater or less extent, and affords, on its inner side, an articular surface for part of the acromial end of the clavicle: the inner process is short and compressed, and is also joined by ligament to the acromial end of the clavicle. Just below the origins of these processes an articular surface extends transversely across the posterior part of the coracoid bone by which it is firmly united by fibro-cartilaginous substance to the scapula. The glenoid cavity resulting from the union of these two bones is not, however, always equal to the reception of the entire head of the humerus. In the birds, which Mr. Vigors regards as composing the typical orders of the class, viz. the *Raptores* and *Insessores*, (the *aves aereæ* of Nitzsch,) a small but distinct bone extends between the scapula and coracoideum along the superior part of the articular cavity for the humerus, which it thus completes. Nitzsch, the discoverer of this element of the scapular apparatus, denominates it the capsular bone, (*Schulterkapselbeine*); by Meckel it is called the *Os humero-scapulare*, and is regarded as the analogue of the *scapula inferior* of reptiles. In the Aberrant orders of birds, as the *Rasores*, *Grallatores*, and *Natatores*, there is, in place of this bone, a strong elastic ligament or fibro-cartilage extended between the scapula and coracoideum, against which that part of the head of the humerus rests, which is not in contact with the glenoid cavity.

The *clavicles* (*v*, *fig.* 125, *b*, *fig.* 130) in birfls, as in the mammalia, are the most variable elements of the scapular apparatus. In the Ground Parrots of Australia (*Pezophorus*, Illiger) they are rudimentary or wholly deficient;* they are represented by short processes in the Emeu, Rhea, and Cassowary; they do not come in contact inferiorly in the Ostrich, although they reach the sternum. In the Toucans they are separate, and do not reach the sternum. In the Hornbills and Screech Owl (*Strix ulula*) they are united at their inferior extremities by cartilage. In the rest of the class they are anchylosed together inferiorly, and so constitute one bone, the *furculum*, or *merrythought*. From the point of union a compressed process extends downwards in the *Diurnal Raptores*, the *Conirostral Insessores*, the *Rasores*, most of the *Grallatores*, and *Natatores*, in which a ligament extends from its extremity to the ento-sternum. The process itself reaches the sternum, and is anchylosed therewith in the Pelicans, Cormorants, Grebes, Petrels, and Tropic-bird; also in the Gigantic Crane, and Storks in general. In the Humming-birds, where the sternum is so disproportionately developed, the furculum terminates almost opposite the commencement of the keel, but at some distance before it; in those species in which we have examined it, belonging to the genus *Trochilus*, *Lacèp.* it is of equal length with the coracoideum, and not shorter, as Meckel asserts. As the principal use of this elastic bony arch is to oppose the forces which tend to press the humeri inwards towards the mesial plane, during the downward stroke of the wing, and restore them to their former position, the clavicles composing it are stronger, and the angle of their union is more open, as the powers of flight are enjoyed in greater perfection; of this adjustment the Swifts, Goat-suckers, and Diurnal Birds of Prey afford the best examples.

Notwithstanding the anterior extremity is limited to one function, and the motions of its parts are confined to simple folding and extension, it contains the same number of joints as the arm of the Monkey, or of Man himself. We shall now successively consider the bones of the *Brachium*, *Antibrachium*, *Carpus*, *Metacarpus*, *and Digits*.

The brachium, or *humerus* (*w*, *fig.* 125, *m*, *fig.* 130) is prineipally characterized by the forms of its extremities. The head, or proximal extremity, is transversely oblong to play in the articular cavity formed by the union of the scapula and coracoid bone. It is further enlarged by two lateral crests: of these the superior, or external, which is angular, with the thin margin turned forward, affords an adequate attachment to the great pectoral muscle: the opposite process has its margin rounded and curved backwards, and it is beneath the arch thus formed that the orifices are situated, by which the air penetrates to the cavity of the bone. There is always a deep depression at this part, even in birds which have no air in the humerus, as in the Penguins and Ostrich. The distal end of the humerus is not less characteristic of the bird, and different from that of other vertebrate animals. The articular hinge is divided into two parts, one internal, which is the largest, for the ulna, of an almost spherical form, and one external, for the radius, of an elongated figure, extending for some distance along the anterior surface of the humerus. The radius is thus made to describe in the act of bending a greater portion of a circle than the ulna, and the whole fore-arm moves in a plane which is not perpendicular to the anterior surface of the humerus.

The humerus is not always developed in length in proportion to the powers of flight; for although it is shortest in the Struthious Birds and Penguins, it is also very short in the Swifts and Humming-birds. In the latter, however, it is characterized by its thickness and strength, the size of its muscular processes, and the consequent transverse extension of its extremities; while in the *Cursores* it is as attenuated as it is short, and in the Penguins is reduced to a mere lamina of bone resembling the corresponding part in the paddle of the turtle. In the *Rasores* it rarely equals half the length of the body; in most other birds it is about two-thirds that length; it attains its greatest length in the Albatross. In this and other sea-birds, as the Gulls, Awks, and Petrels,

* Mr. Vigors has noticed the absence of the os furcatorium in *Psittacus mitratus*, *Platycercus eximius*, and *Psittacula Galgula*.

the humerus presents a notable process at the outer side, near its lower extremity; and in the Puffin (*Fratercula arctica*) an ossiculum is moveably articulated to this process.

Another ossiculum may here be noticed, although it belongs rather to the *ulna*, being essentially the separated olecranon of that bone. This detached sesamoid bone is found attached (like the patella of the knee-joint) to the capsular ligament and the tendons of the extensor muscles, in many of the Raptores, and in the Swifts. In the Penguins it is double (*n, n, fig.* 130.)

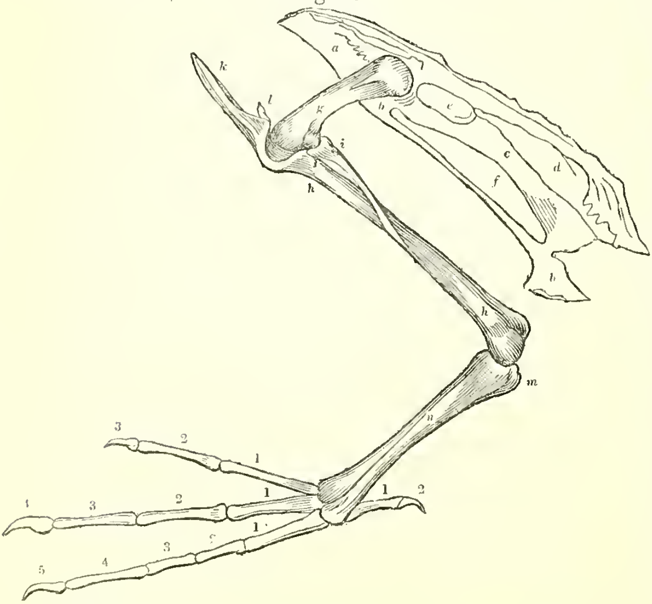
Of the two bones of the antibrachium (*y, fig.* 125) the *ulnar* (*o, fig.* 130) is always the strongest, and especially so in the *Struthiones:* both this and the *radius* (*p, fig.* 130) are in general slender and straight bones, slightly enlarged at their extremities, placed not by the side of, but one in front of the other, and so articulated together, and with the humerus, as to admit of scarcely any degree of pronation or supination, which, as Meckel justly remarks, adds to that firmness and resisting power in the anterior member which are so necessary during the actions of flight. In the Penguins, the bones of the fore-arm present the same modifications as the humerus in relation to the corresponding action in the denser element, or that of swimming: they are flattened, and are articulated with the anterior edge, and not the extremity of the humerus.

The bones of the hand are extended in length, but restricted in lateral development. The *carpus* consists of two bones only, (*q, fig.* 130,) so wedged in between the antibrachium and metacarpus, as to limit the motions of the hand to those of abduction and adduction necessary for the folding up and expansion of the wing; the hand is thus fixed in a state of pronation; all power of flexion, extension, or of rotation, is removed from the wrist-joint, so that the wing strikes firmly, and with the full force of the contraction of the depressor muscles, upon the resisting air.

The *metacarpus* is principally formed of two bones, anchylosed together at both extremities (*r, r, fig.* 130); of these, the one which corresponds to the radius is always the largest, and supports the finger which has the greatest number of phalanges: a third small rudimental bone is in most birds found anchylosed to the outer-side of its proximal extremity, and this supports the single phalanx of what is usually called the thumb. The longest or radial finger is generally composed of two phalanges (*s, s, fig.* 130) of moderate length; to which, in some birds, a third smaller phalanx is added. The ulnar finger consists of a single phalanx only (*t, fig.* 130). These are strongly bound together by ligaments and integument, so that the wing loses nothing of its force, while it preserves in these separated bones its analogy with the anterior extremities in the other vertebrated classes. In Zoology the large feathers that are attached to the ulnar side of the hand, are termed *Primariæ* or primary feathers; those which are attached to the fore-arm *Secundariæ*, or secundaries, and *Tectrices*, or wing-coverts; those which lie over the humerus are called *Scapulariæ*, or scapularies; and those which are attached to the thumb, *Spuriæ*, or bastard feathers. In some birds the wing is armed with a spur attached to a phalanx at the radial side of the so-called thumb, which, as Nitzsch observes, would therefore seem analogous to the index finger.

The bones of the leg or posterior extremity (*fig.* 131) do not exactly correspond, in their divisions or principal groups, to those of the wing, the segment corresponding to the carpus being invariably blended with the one that succeeds.

Fig. 131.



Pelvis and bones of the leg of the Diver, or Loon.—Colymbus glacialis.

The *pelvic bones* present a remarkable contrast to those of the shoulder, being always anchylosed on either side into one piece, but being with one exception; never joined in the mesial line, while this is the only place where the elements of the scapular apparatus are in general united by bone. In the young bird the *os innominatum* is seen to be formed by the usual three bones, viz. the *ilium*, *ischium*, and *pubis*, corresponding respectively to the *scapula*, *coracoid*, and *clavicle*, of the anterior extremity.

The *ilium* (*δ, fig.* 125, *a, fig.* 131.) is the only bone of the pelvis which comes in contact with the vertebral column, and it extends from the posterior dorsal vertebræ along the whole of the sacrum, to which it is early united by anchylosis. At its posterior extremity it is expanded laterally and becomes anchylosed with the ischium (*c*, *fig.* 131) posterior to the ischiadic notch (*e*, *fig.* 131) which is thus converted into a foramen.

The ilium is of a considerable size, of an elongated form, expanded at its extremities and contracted in the middle; the anterior expansion is concave externally, the posterior on the contrary convex. Besides being anchylosed with the ischium and sacrum, the spinous and transverse processes of one or two posterior dorsal vertebræ are commonly joined to it by bony union. In the Penguins, however, where the posterior extremities are ill adapted for supporting the body in progressive motion on land, the ilium appears at no time to be anchylosed with any part of the vertebral column.

The *os pubis* (ζ, *fig.* 125, *b b*, *fig.* 131) does not extend to meet its fellow on the mesial line, but is commonly directed backwards like a long bent styliform process (3, *fig.* 134), adapted to allow a safe passage to the large and fragile eggs. In general it unites with the ischium so as to complete the obturator foramen (*f*, *fig.* 131), behind which another foramen is occasionally formed by a second union with the ischium, as is seen in the Humming-bird; while in other Birds, as the Stork, it is only united to the ischium at the cotyloid foramen, and the obturator hole communicates with a long fissure and is completed posteriorly by ligament only. The cotyloid cavity for the head of the thigh-bone is always incomplete at its posterior or internal part, which is closed in the recent state by a strong aponeurosis.

The *ischium* (*c*, *fig.* 131) is a small elongated bone, slightly convex externally, extending from the acetabulum backwards, parallel with the ilium.

In the Struthious Birds the pelvis is proportionally very long, but narrow; the ossa innominata cover the whole of the sacrum, meeting and joining above that part like the roof of a dwelling. In the *Rhea*, or American Ostrich, the ischiadic bones meet below the sacrum, where they are united for a considerable extent by a symphysis, so that the sacrum is closely surrounded, and in fact its place is almost supplied by the ossa innominata, for the development of the included vertebræ is in consequence so much impeded, that they can scarcely be detected at this part; beyond which, however, the coccygeal vertebræ suddenly resume their ordinary magnitude. This union of the ischia does not take place in the other Struthious birds; but the Ostrich presents the remarkable exception, among Birds, of the completion of the pelvic circle by the anchyloses of the pubic bones at their inferior extremities.

The *femur* (θ, *fig.* 125, *g*, *fig.* 131) is a short cylindrical bone, deviating from the straight line by a very slight anterior convexity. The head is a small hemisphere; joined, without the intervention of a neck, at a right angle, to the shaft of the bone: it presents at its upper part, a considerable depression for the attachment of the round ligament. The single large trochanter generally rises above the articular eminence, and is continuous with the outer side of the shaft. The orifice for the admission of air into the bone is situated anterior to this cavity. The femur is most readily characterised by the form of its lower extremity: this presents as usual two condyles, the inner one corresponding to the tibia, the outer one, which is the largest and the longest, resting both upon the tibia and fibula; upon this condyle a semicircular rounded eminence is observed extending from the front to the back part, and being lost in a depression at both extremities; the result of this structure is to put the external lateral ligament upon the stretch when the fibula is passing over the middle of the condyle, and that ligament, being elastic, pulls the fibula into the cavity in which the ridge terminates, with a jerk—whether the motion be that of flexion or extension, in either of which conditions the leg is by this structure the more firmly locked to the thigh. It has been denied that the spring-joint ever exists at the knee, and it is probable that all birds do not possess the requisite structure in the same perfection; but a common indigenous species, the Water-hen, (*Gallinula Chloropus*) affords a good example of the beautiful mechanism in question. The femur attains its greatest development in the Ostrich; but in this species it is short in comparison to the other bones of the leg, the length of which in the Stilt-bird and other Waders is attained solely by the elongation of the tibia and metatarsus.

The *tibia* (ι, *fig.* 125, *h h*, *fig.* 131) is the principal bone of the leg—the *fibula* (κ, *fig.* 125, *i*, *fig.* 131) appearing as a mere styliform process tapering to a point below, and anchylosed for a greater or less extent to the tibia. The tibia is of a triangular form, especially at its enlarged superior extremity, the articular surface of which is unequal, being flat internally, convex at the centre, and concave externally and in front. The inferior articular surface of the tibia forms a considerable transverse trochlea, above which anteriorly there is a deep depression. In general an osseous bridge extends transversely across this depression, converting it into a foramen through which the tendon of the *Extensor communis digitorum* passes.

In the Divers, Grebes, Guillemots, and Albatrosses the middle and internal crests of the tibia unite superiorly and are extended upwards into a long pointed process (*k*, *fig.* 131) directed inwards and forwards, anterior to, but not supplying the place of, the patella, (*l*, *fig.* 131) which will be always found as a distinct bone behind this process. The process is most developed in the genus *Colymbus*, and affords extensive attachments by way of insertion to the extensors of the tibia, and by way of origin to the extensors of the metatarsus; by means of the latter disposition the power of the back stroke of the foot is increased.

The *Tarsus* can only be recognized as a distinct segment of the leg when the bones of a very young Bird are examined. But in the Ostrich, even when it has attained a third of its natural size, the Astragalus remains ununited to the metatarsus. It is a flattened transversely oval bone, convex in the middle of its upper surface, and irregularly flattened below, where it is adapted to the three still partially separated bones of the metatarsus. A rudiment of the os calcis may be observed in the detached bone which is found in the tendons of the extensors of the foot near their insertion. The Capercailzie (*Tetrao urogallus*) affords a good example of this structure. The process (*m*, *fig.* 131) in which the above tendons are inserted, and which is very prominent in the *Rasores*, *Grallatores*, and *Natatores*, must also be regarded as appertaining to the tarsal series, since it commences by a separate ossification.

In most birds, however, the tendo Achillis has no sesamoid bone to add to its leverage, and in all birds the astragalus is soon anchylosed to the metatarsus, constituting with it one elongated tarso-metatarsal bone (λ, *fig.* 125, *n*, *fig.* 131). Traces of the number of laterally anchylosed pieces of which the metatarsus is composed are always more or less indicated by longitudinal grooves. In the Penguins, indeed, the anchylosis of the three metatarsal bones takes place at their extremities only, and they are consequently separated from each other in the greater part of their extent. They are also disproportionately short, and bent forwards upon the tibia, so as to increase the surface of support required by these birds when standing in their usually erect position. In the *Grallatores* and *Struthiones*, on the contrary, the tarso-metatarsal bone is remarkably elongated, the extraordinary length of leg in these birds depending chiefly upon the extent of this segment of the limb.

In the Stork and congeneric birds, which sleep on one leg, the ankle-joint presents a mechanism analogous to that which we have above described in the knee-joint. Here, however, the projection which causes the extension of the elastic ligaments in the motion of the joint is in the inferior bone. Dr. Macartney thus describes the mechanism: " There arises, from the fore-part of the head of the metatarsal bone, a round eminence, which passes up between the projections of the pulley on the anterior part of the end of the tibia. This eminence affords a sufficient degree of resistance to the flexion of the leg to counteract the effect of the oscillations of the body, and would prove an insurmountable obstruction to the motion of the joint, if there were not a socket within the upper part of the pulley of the tibia to receive it when the leg is in a bent position. The lower edge of the socket is prominent and sharp, and presents a sort of barrier to the admission of the eminence that requires a voluntary muscular exertion of the bird to overcome, which being accomplished it slips in with some force like the end of a dislocated bone."* It must be added, that the elastic lateral ligaments contribute also to jerk the metatarsal tubercle into the tibial cavities, and to resist its displacement.

The lower extremity of the metatarsus is divided into three articular eminences, corresponding to the ordinary number of anterior toes. These eminences are convex from before backwards, and the middle one, which is the longest, is converted into a pulley by a mesial groove which traverses it in the same direction. The lateral surfaces are simply convex, and very narrow; of these the internal is the shortest, except in the raptorial birds. At the extremities of the grooves which indicate the lateral juxtaposition of the metatarsal pieces, there are ordinarily foramina extending from before backwards through the bone.

A fourth articular surface is observable in most birds on the inner and posterior side of the metatarsal bone; this is situated on an accessory piece which always commences by a separate ossification, although in some birds it afterwards becomes anchylosed with the innermost of the other juxtaposed components of the metatarsus. When this does not take place, the metatarsus presents a rough, more or less irregular, oval surface, for the firm ligamentous attachment of the accessory bone which supports the back toe, usually termed the *hallux* or posterior thumb. This articulating surface is important as affording a good distinctive character for identifying the bones of birds in a fossil state, and the more so as its position is indicative of the powers of grasping or perching —being placed low down, on a level with the anterior toes, in those birds which enjoy the insessorial power in the greatest perfection, and being gradually removed higher and higher in the Waders, until it is at length wholly lost, as in the genus *Cursorius*, the Bustards, and the Struthious family. In the Petrel, however, this accessory metatarsal bone is wanting, although the hallux is present, the two bones of which are therefore united to the principal metatarsal bone by long ligaments. The tarso-metatarsal bone is further characterized by sharp longitudinal ridges of bone on the posterior surface, which afford attachment to the aponeurotic thecæ confining the tendons which glide along the metatarsus to the toes.

In birds, as in mammalia, the number of toes is subject to great variety; if the spur of the Gallinaceous tribe be regarded as one, we may then reckon the ordinary number of five in these birds, while in the Ostrich the toes are reduced to two. Birds are, however, the only class of animals in which the toes, whatever be their number or relative size, always differ in the number of their phalanges, yet at the same time preserve a constancy in that variation.

The following is a tabular view of the numerical relation in the osseous parts of the feet of

* See Transactions of the Royal Irish Academy, vol. xiii. p. 20.

birds according to the researches of Cuvier, the discoverer of this remarkable peculiarity in the anatomy of birds.

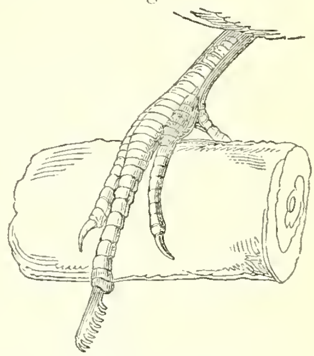
Table of the number of toe phalanges in Birds.

	Number of Phalanges in the				
	First or inner-most toe or *Calcar.*	Second, com-monly called the *Hallux.*	Third.	Fourth.	Fifth or outer-most, or little toe.
1 Cock (*Gallus*), Pheasants (*Phasianus*), Turkeys, Peacocks (*Pavo* and *Lophophorus*) . .	1*	2	3	4	5
2 *Raptores, Insessores, Columbidæ, Cracidæ, Tetraonidæ*, and the rest of the class, except		2†	3‡	4§	5‖
3 The Genera, *Rhea, Dromaius, Casuarius, Otis, Cursorius, Charadrius, Hæmatopus, Arenaria, Falcinella, Himantopus, Halodroma, Diomedea* .			3	4	5
4 The Ostrich (*Struthio*) .				4	5

The above table shows what are the toes which are deficient in those birds that do not possess the ordinary number.

The phalanges are expanded at their extremities, especially at the posterior; the articular surfaces are concave at this end, but divided longitudinally by a narrow convex line, to which a corresponding unequal surface at the anterior end of the preceding phalanx is adapted, constituting a ginglymoid articulation. The ultimate or ungueal phalanges are characterised by their anterior pointed terminations, which correspond in form, in some degree, to the nature of the claw.

Fig. 132.



Foot of the Goat-sucker.

Of the fossil bones of birds.—Birds differ from each other in a much less degree than quadrupeds, less, perhaps, than any other class. The Penguin and the Ostrich have, indeed, but a remote external resemblance with the Eagle or the Swallow, but yet they have never been regarded as other than birds. The Porpesse and the Whale, on the other hand, although their real affinities were pointed out by Aristotle, have been placed by many subsequent Zoologists in a very different class from the Lion or the Ape, and in the older systems of Natural History they always obtained their position among the true fishes.

Osteological characters of the same value with those which serve to distinguish the genera, and for the most part the species of Mammalia, are, therefore, with difficulty found in the Class of Birds. Cuvier has declared that the differences in the skeleton of two species of an ornithological genus are sometimes wholly inappreciable, and that the osteological characters of *Genera* can rarely be detected in any other part than in the bones of the mandibles, which do not always conform in a sufficiently characteristic manner with the modifications of the horny bill.

The determination of the fossil bones of this class is, therefore, conjectural, or, at least, it wants much of that demonstrative character which the bones of quadrupeds afford.

The fossil bones of birds described by Cuvier are considered by him to appertain to a species of Buzzard, Owl, Quail, Woodcock, Ibis, Sea-lark, and Cormorant; and, although not remarkable for their number or for their zoological interest, yet they demonstrate that the species which existed at that remote period, when the Anoplotheriums and other extinct quadrupeds trod the face of the earth, had the same proportion of parts, the same length of wings and legs, the same articulations of the toes, the same form and numerical proportions of the vertebræ; in short, that their whole organization was regulated by the same general

* This is wanting in the Argus Pheasant; the *Pavo bicalcaratus*, on the contrary, has two spurs on each metatarsal bone.

† In the single genus *Ceyx* among the Insessores, and *Hemipodius* among the *Rasores*, this toe is wanting. In all the rest, with the exception of the Swifts (*Cypselus*) it is directed backwards.

‡ In the Dentirostral Insessores this toe is united by one or two phalanges to the fourth.

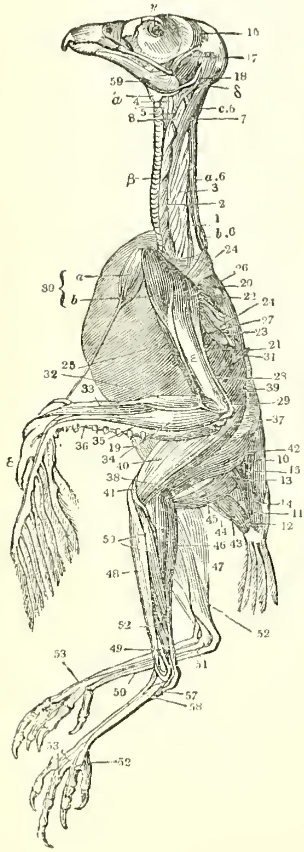
§ According to Cuvier this toe and the fifth in the Swift (*Cypselus*) have only three phalanges like the third. In the Goat-suckers (*Caprimulgus*) and Herons (*Ardea*) the claw of this toe is provided with dentations similar to a comb on its inner side.

‖ This toe is stated by Cuvier to have only four phalanges in the Goat-suckers, and we have ascertained the correctness of the exception, and that it also obtains in the Rhea. This toe is united to the fourth toe as far as the penultimate joint in the Bee-eaters (*Merops*), the Motmots (*Prionites*), the King-fishers (*Alcedo*), the Todies (*Todus*), and the Hornbills (*Buceros*), which form in consequence the family *Syndactyli* of Cuvier. In the *Scansores* this toe is turned backwards, and assists the *Hallux* in opposing the other toes. The Owls have the power of turning back the outer toe at pleasure.

laws of co-existence and all that relates to the nature of the organs and their essential functions, as at the present day. They afford no evidence, not even a trace of any part having been lengthened or curtailed, or otherwise progressively modified, either by the operation of external causes or by internal voluntary impulse.

Myology.—The muscular system of Birds is remarkable for the distinctness and density of the carneous fibres, their deep red colour, and their marked separation from the tendons, which are of a brilliant shining colour, and have a peculiar tendency to ossification. This high degree of development results from the rapid circulation of very warm blood, which is highly oxygenated in consequence of the activity and extent of the respiratory function. The energy of the muscular contraction in this class is in the ratio of the activity of the vital functions, but its permanent irritability is proportionally low, as Carus has justly observed.

Fig. 133.



Muscles of a Sparrow-hawk.

These characteristic properties are manifested in the greatest degree in the muscles of those families of the *Insessores* which take their food on the wing, as the *Hirundinidæ* and *Trochilidæ* (Swallows and Humming-birds); in the *Diurnal Raptores* and in the long-winged *Palmipedes*, as the Albatross, Tropic Bird, &c. In the more heavy and slow-moving Herbivorous families, and in the short-winged *Swimmers*, as the Penguins, &c. the muscles resemble those of the Reptilia in their softness and pale-colour.

The mechanical disposition of the muscular system is admirably adapted to the aerial locomotion of this class; the principal masses being collected below the centre of gravity, beneath the sternum, beneath the pelvis, and upon the thighs, they act like the ballast of a vessel and assist in maintaining the steadiness of the body during flight, while at the same time the extremities require only long and thin tendons for the communication of the muscular influence to them and are thereby rendered light and slender.

Muscles of the trunk.—The muscles of the cervical region are the most developed, as might be expected from the size and mobility of this part of the spine; the muscles which are situated on the dorsal and lumbar regions are, on the other hand, very indistinct, feeble, and but slightly carneous; they are not, however, entirely wanting.

The *Semi-spinalis dorsi* or *Opisthotenar*, is easily recognizable, occupying the space between the spinous and transverse processes, arising from the anterior margin of the ilium and the transverse processes of the sacrum, and attached by means of long tendons to the transverse processes of the costal vertebræ. It is most developed in those birds which have the greatest mobility in this part of the spine, as in the Penguins, in which the external venter of the muscle is well developed, inserted into the vertebral ends of the ribs, and adapted to support the body in the erect position which these birds assume while standing.

On the mesial aspect of this muscle and somewhat covered by it, the *Spinalis dorsi* may be distinctly traced, passing from the spinous processes behind, to those at the anterior part of the trunk and beginning of the neck.

The *Cervicalis ascendens* (1, *fig.* 133) is the chief extensor of the neck: it rises from the spines of the anterior dorsal vertebræ, and is inserted by long and separate fasciculi into the posterior articular processes of the second, third, and fourth cervical vertebræ. In this course it receives descending slips of muscle from the spines of the inferior cervical vertebræ, and ascending fasciculi, which furnish tendons to the fifth and sixth vertebræ, and to the atlas, so that it is enabled to extend the neck even while the head is raised.

Muscles corresponding to the *Intertransversales* (2) are continued on the neck from the external belly of the *Opisthotenar;* these slips extend from the articular processes of the dorsal vertebræ to those of the inferior cervical. Posterior to the *Intertransversales*, the *Semispinalis colli* (3) is seen passing from the transverse to the spinous processes.

The *Longus colli* arises from the anterior spinous processes of the dorsal vertebræ and from the anterior part of the cervical vertebræ, and these slips diverge to be inserted into the transverse processes, and their appended styles or spurious ribs.

A superadded muscle, which may be regarded as a continuation of the preceding, and which corresponds to the increased number of the vertebræ of the neck, passes from the transverse processes of the five superior vertebræ to the anterior spines of the vertebræ immediately anterior—a portion of this muscle is shown at 5.

No. 6 indicates one of the most remarkable muscles in the cervical region of Birds; it is analogous to the *Biventer cervicis* of mammals, but has a much longer and more distinct middle tendon, *a*. 6. Its lower or posterior venter, *b*. 6, arises by a tendon, most commonly from the short spinous processes of the lowest cervical vertebræ, the anterior fleshy part *c* is inserted into the squamous spine of the occiput. This muscle is well developed in the Ostrich, where it arises as low down as from the last lumbar vertebra, by a long tendon, which is continued to the cervical region before it joins the fleshy portion, the whole muscle affording a striking example of the peculiar development of the tendinous over the carneous part which characterizes the muscular system of Birds. In the Parrots and Raptorial birds, however, the carneous exceeds the tendinous part of this muscle.

The *Complexus* (7) arises from the articular and transverse processes of a variable number of the superior cervical vertebræ, and passes obliquely backwards to be inserted into the occiput, crossing exteriorly the upper belly of the preceding muscle.

The *Trachelo-mastoideus* (8) arises from the articular processes of the cervical vertebræ from the second to the sixth, and is inserted into the posterior part of the *basis cranii.*

Anterior to the preceding muscle a portion of the *Rectus capitis anticus major* may be seen at 4. This muscle is largely developed, arising from the anterior part of the sixth, seventh, and eighth vertebræ, and inserted into the basis cranii. There are also muscles analogous to the *Rectus capitis anticus minor*, the *Recti postici majores et minores*, the *Obliquus externus* or *superior*, and in the Penguin, a strong tendon is given off from the Trachelo-mastoideus which represents the *obliquus inferior* of the neck.

When it is remembered that the cervical region of the spine in Birds is subservient and essential to all the movements and functions of the bill, as a prehensile instrument, and a cleanser of the plumage, we cannot sufficiently admire the endowments of length, flexibility, and muscularity, by which it is enabled to fulfil the important functions of an additional extremity.

In the caudal region of the spine the following muscles present themselves. On the dorsal aspect, the *Levator coccygis* (10) extends from the transverse processes and lower extremity of the sacrum to the superior spines of the coccyx and the base of the last or plough-share vertebra. This muscle may be regarded as a continuation of the spinalis dorsi. Beneath it are found strong *Interspinales* muscles.

The *Quadratus coccygis* (11) arises from the transverse processes of the coccygeal vertebræ and is inserted into the shafts of the *rectrices* or tail-quills, which it separates and raises. On the lateral aspect we find the *Pubo-coccygeus* (12) arising from the posterior margin of the pubis, and inserted also into the shafts of the exterior *rectrices;* it is by means of these muscles in conjunction with the two preceding that the Peacock spreads its gorgeous tail.

The *Ilio-coccygeus* (13) extends from the posterior margin of the ilium to the last coccygeal vertebra, and to the small inferior tail-feathers.

On the ventral or inferior aspect of the tail, the muscles are in general more feebly developed than on the opposite side, except in the Woodpeckers, where the tail, by means of its stiff and pointed quill-feathers, serves as a prop to support the bird on the perpendicular trunks of trees on which it seeks its food. In these the *Ischio-coccygeus* (14) is of large size, extending from the lower edge of the ischiadic tuberosity, and from the transverse processes of the anterior coccygeal vertebræ to the inferior spines of the posterior coccygeal vertebræ, and to the sides of the last compressed or plough-share bone.

The *Depressor coccygis* (15) extends from the ventral aspect of the bodies of the anterior coccygeal vertebræ to the inferior spines of the posterior and to the base of the last vertebra.

Of the *Muscles of the head* those which are attached to it for its general motions have already been described; the remaining muscles of this part are devoted to the movements of the jaws, the tongue, the eye, and the ear. The cutaneous muscles of the face are usually described as being entirely deficient, and the only ones that can be regarded as belonging to this series are the slips of panniculus carnosus, analogous to an *occipito-frontalis* (16), which are chiefly developed in order to elevate the crest-feathers in those birds which possess that ornament; there are also cutaneous slips which belong more properly to the organs of hearing, and which raise the auricular circle of feathers in the Owls, Bustards, &c.

The muscles of the jaws are chiefly modified in relation to the moveable condition of the upper mandible and tympanic bone, and the subserviency of the latter to the actions of these parts.

The *Temporalis* (17) fills the temporal fossa, which consequently indicates the bulk of that muscle in the dry skull. It arises from a greater or less extent of the temporal and parietal bones, and, as it passes within the zygoma, becomes closely blended with the *Masseter;* the united muscles derive an accession of fibres from the lower part of the orbit, and are inserted into the raised superior margin, representing the coronoid process;

and into the sides of the lower jaw from the articulation as far forward as the commencement of the horny bill.

In the Cormorant there projects backwards from the spine or squamous element of the occipital bone, an osseous style about an inch in length, of a trihedral figure and tapering to a point. It is not anchylosed as a process of the occiput, but is moveably articulated to it; and its description has been referred to this section because it does not constitute a regular part of the skeleton, not representing any essential element of the bony fabric, but is to be regarded like the bony tendons of the legs as an ossification of the intermuscular aponeurosis of the temporal muscles to which it affords a more extensive and firmer origin. This, indeed, is its essential use,* for the muscles of the upper part of the neck are inserted into the occipital bone, and glide beneath the posterior or superadded fasciculi of the temporal muscle. Analogous parts appended to the true spinous processes of the vertebræ are met with abundantly in the inferior vertebrate classes, especially in fishes, where they extend frequently above the spines of the whole vertebral column, increasing the surface of origin of the lateral series of muscles.

The muscle analogous to the *Biventer maxillæ* (18) arises by two portions, the one from the lateral depression of the occiput, the other from the depression behind and below the external meatus auditorius; they are inserted into the back part and angle of the lower jaw. A similar disposition of the *digastricus* is met with in many of the mammalia; even in the *Orang-utan (Simia Satyrus)* it is equally devoid of a central tendon, and is unconnected with the os hyoides.

The openers and closers of the mandibles present very slight differences of bulk in relation to the development of the parts they are destined to move; their disproportion to the bill is, on the contrary, truly remarkable in the Horn-bills, Toucans, and Pelican, and the bill is but weakly closed in these in comparison with the shorter-billed birds.

The upper mandible is moved by three muscles on either side. The first is of a radiated form, arises from the septum of the orbits, and converges to be inserted into the external and posterior end of the pterygoid bone, just where this is articulated to the tympanic bone. It draws forward the pterygoid bone, which pushes against and raises the upper jaw.

The second muscle analogous to the *External Pterygoid* arises from the space between the posterior part of the orbit and external meatus auditorius, and is inserted into the internal process and contiguous surface of the tympanic bone; it affects the pterygoid process, and consequently the upper mandible in the same way as the preceding muscles, and assists in opening the bill.

The *Pterygoideus Internus* is a long and slender muscle; it arises from the pterygoid process and body of the sphenoid, and is inserted principally into the inner side of the lower jaw and tympanic bone; it also sends off a small tendon to the membrane of the palate. This muscle draws forward the lower jaw and depresses the upper one.

In the Cross-bill *(Loxia curvirostra)* there is a remarkable want of symmetry in the muscles of the jaws on the two sides of the head corresponding to their peculiar position. Those of the side towards which the lower jaw is drawn in a state of rest (which varies in different individuals) are most developed, and act upon the mandibles with a force that enables the bird to dislodge the seeds of the fir-cones, which constitute its food.

The articulation of the lower jaw is strengthened and its movements restrained by two strong ligaments, one of these *(a)* is extended from the ligament completing the lower part of the orbit, or from the zygomatic process of the temporal bone, and is inserted at the outer protuberance near the joint of the lower jaw, and must prevent the bill from being too widely opened. The second ligament extends from the zygomatic process of the temporal bone directly backwards to the posterior part of the articular depression of the lower jaw, and is designed to guard against the backward dislocation of the lower jaw.

The muscles of the ribs. — The *levatores costarum* arise from the posterior part of the extremities of the transverse processes, and converge to be inserted into the anterior margin of the succeeding posterior rib. Those of the first and second ribs represent the *Scaleni*, and are of larger size, arising from the last and penultimate cervical vertebræ.

The *Intercostales externi* appear to be continuations of the *Levatores costarum*, and are usually divided into an anterior and posterior moiety corresponding to the marked separation and moveable articulation between the vertebral and sternal portions of the ribs; the anterior division arises from the costal appendage and extends to the anterior extremity of the rib; to afford a more advantageous origin to this inspiratory muscle would appear, therefore, to be one of the uses of the costal appendages, as well as to strengthen the connection of the ribs to each other.

The *Internal intercostals* commence at the sternal extremities of the ribs, as in mammalia, but extend backwards no farther than the costal appendages; their fibres run in an opposite direction to the external intercostals, and are shorter, the insertion into the posterior succeeding rib being by a thin but wide aponeurosis: in the Penguin they are, however, wholly muscular. Two other layers of intercostal muscles, corresponding to the triangularis sterni, and having the same direction of fibres, are extended from before backwards and outwards to the four anterior sternal portions of the ribs; arising from the superior and external angle of the sternum.

The muscles of the abdomen are small and

* See Yarrell 'On the Anatomy of the Cormorant,' Zool. Trans. v. iv. p. 235.

weak, in consequence of the protection which the extended sternum affords to the viscera of that cavity.

The *External oblique* (19) is chiefly remarkable for the transverse arrangement of its fibres; these arise anteriorly by short fleshy digitations from the inferior ribs, and by a large but very thin tendon from the posterior ribs and the edge of the ilium and pubis; they are inserted by aponeurosis into the anterior margin of the pubis, and join the aponeurosis of the opposite muscle in front of the thin and tendinous *rectus abdominis*. This muscle, by drawing downwards and backwards the posterior part of the sternum and sternal ribs, opens the angle between these and the vertebral ribs, depresses, in consequence, the anterior part of the sternum, and thus dilates the thorax, and becomes a muscle of *inspiration*.

The *Internal oblique* comes off fleshy from the anterior moiety of the edge of the pubis, and tendinous from the posterior moiety of the same bone; it is much smaller than the preceding, and is directed forwards and inwards to the last rib, which it draws backwards, and thus assists the preceding in the compression of the abdomen and abdominal air-cells, and in the dilatation of the thorax.

The *Transversalis* is a muscle of greater extent; it arises from the whole anterior margin of the pubic bones by carneous fibres, and by digitations from the three posterior ribs; its tendon unites with that of its fellow in the mesial line, extends immediately over the peritoneum over the whole abdomen as far as the posterior margin of the sternum to which it is attached.

The *Rectus abdominis* is not intersected by tendinous digitations; its origin is by a broad thin tendon from the lower and posterior half of the pubis; at about the middle third of the abdomen it becomes carneous, and is inserted into the posterior margin of the sternum. A mesial tendon or linea alba separates the fleshy portions of the two muscles.

The *Diaphragm* arises by fleshy digitations from the sternal ribs; in the Ostrich these digitations are five in number on either side: the carneous fasciculi do not, however, extend so far upon the central aponeurosis as even to be united laterally to one another, and consequently this muscle has frequently been denied to birds. From the lungs being confined to the back part of the thorax, the diaphragmatic aponeurosis attached to their inferior surface is not extended as a transverse septum between the chest and abdomen, but allows the heart to encroach upon the interspace of the lobes of the liver, as in reptiles. The contraction of the muscle tends directly to dilate the lungs, but is less perfect as an inspiratory action from the aponeurosis or central tendon being perforated by large cribriform apertures for the passage of the air into the abdominal air-cells.

The Wing-Muscles.—The muscles of the anterior extremity, especially those inserted into the humerus, are prodigiously developed, and form the most characteristic muscles of the bird. The muscles of the shoulder, however, are but small, and those of the distal segments of the wing still more feeble.

The *Trapezius* (20), the lower half of which seems only to be present in birds, arises from the spines of the lower cervical, and a varying number of the contiguous dorsal vertebræ, and is inserted into the dorsal margin of the scapula and the corresponding extremity of the clavicle; the clavicular portion can commonly be separated from the scapular.

The *Rhomboideus* lies immediately beneath the preceding, and is always single; it passes in a direction contrary to the trapezius from the spines of the anterior dorsal vertebræ to the dorsal edge of the scapula.

The *Levator scapulæ* arises by digitations from the transverse process of the last cervical vertebra, and from the first two ribs; it is inserted into the posterior part of the dorsal edge of the scapula, which it raises and pulls forwards.

The *Serratus magnus anticus* (21) is most developed in birds of prey; it arises by large digitations from three or four of the middle ribs, and converges to be inserted into the extremity of the scapula.

The *Serratus parvus anticus* or *Pectoralis minor*, as it is termed in Man, arises by digitations from the first and second ribs, and is inserted into the commencement of the inferior margin of the scapula. This is the largest of the muscles of the scapula in the Penguins.

A muscle, which may be regarded either as a portion of the *Pectoralis minor* or as the analogue of the *Subclavius* muscle, arises from the anterior angle of the sternum, and is inserted into the external margin of the sternal extremity of the coracoid bone.

The *Supra-spinatus* (22) arises from the anterior part of the outer surface of the scapula, and is inserted behind the largely developed internal tuberosity of the humerus.

The muscle which seems to represent both the *Infra-spinatus* and *Teres major* (23) has a more extensive origin from the outer margin of the scapula to its extremity, and is inserted into the internal tuberosity of the humerus.

The *Subscapularis* arises from the anterior part of the inner surface of the scapula, and is inserted into the humeral tuberosity. It is divided into two portions by the *Pectoralis minor*.

The *Latissimus dorsi* (24, 24,) is but a feeble muscle in this class, and is constantly divided into two very distinct slips. The anterior portion arises, more superficial than the trapezius, from the spines of the four or five anterior dorsal vertebræ, and is inserted near the tendon of the deltoid into the outer side of the humerus. The posterior slip comes from the spines of the dorsal vertebræ above the origin of the *glutæus magnus*, and sometimes from the anterior margin of the same muscle, and is inserted by a broad and thin tendon immediately in front of the preceding portion.

The *Deltoides* (26) is comparatively a small muscle; it arises from the anterior part of the scapula, and is inserted along the middle of the outer side of the humerus; it brings the wing upward and backward.

Birds have the *Pectoralis* muscle divided, as in many of the mammalia, into three portions, which are so distinct as to be regarded as separate muscles; they all arise from the enormous sternum, and act upon the proximal extremity of the humerus.

The *first* or *great Pectoral muscle* (25) is extraordinarily developed, and is in general the largest muscle of the body. In birds of flight it often equals in weight all the other muscles of the body put together. It arises from the anterior part of the outer surface of the clavicle or furculum, from the keel of the sternum and from the posterior and external part of the lower surface of that bone; it is inserted by an extended fleshy margin into the inner side of the anterior crest of the humerus. It forcibly depresses the humerus, and consequently forms the principal instrument in flight.

This muscle is very long and wide in the *Natatores* generally, but in many of these birds, as the Penguin, its origin is limited to the external margin of the subjacent pectoral muscle, which is here remarkably developed. The great pectoral is very long, but not very thick in the *Rasores*. In the *Herons* it is shorter, but much stronger and thicker. Its size is most remarkable in the Humming-birds, Swallows, and diurnal Birds of Prey, where it is attached to almost the whole outer surface of the sternum and its crest, and has an extended insertion into the humerus.

In the Ostrich its origin is limited to the anterior and external eighth part of the sternum, and it is inserted by a feeble tendon into the commencement of the crest of the humerus, to which it gives a strong rotatory motion forwards.

The *second Pectoral muscle* is situated beneath the preceding; it has the form of an elongated triangle: it arises from the base of the crest of the sternum and from the mesial part of the inferior surface of that bone; it increases in size as it ascends, then again becomes suddenly contracted, passes upwards and backwards round the coracoideum, between that bone and the clavicle, then turns downwards and outwards, and is inserted, fleshy, above and in front of the great pectoral, into the upper extremity of the humeral crest.

The interspace between the clavicle, coracoid, and scapula, through which its tendon passes, serves as a pulley, by means of which the direction of the force of the carneous fibres is changed, and although these fibres ascend from below towards their insertion, yet they forcibly raise the humerus, and thus a *levator* of the wing is placed without inconvenience on the lower part of the trunk, and the centre of gravity proportionally depressed.

In the Penguins, Guillemots, and Gulls, this muscle is almost the largest of the three, occupying the whole length of the sternum. It is remarkable for the length and strength of its tendon, which is inserted so as to draw forwards the humerus with great force. It is proportionally the smallest in the *Raptores*; and is very small and slender in the Struthious birds.

We have already alluded to the use which the Penguin makes of its diminutive anterior extremities as water-wings, or fins; to raise these after making the down-stroke obviously requires a greater effort in water than a bird of flight makes in raising its wings in air: hence the necessity for a stronger development of the second pectoral muscle in this and other Diving Birds, in all of which the wings are the chief organs of locomotion, in that action, and consequently require as powerful a development of the pectoral muscles as the generality of Birds of Flight.

The *third Pectoral muscle*, which is in general the smallest of the three, arises from the anterior part of the inferior surface of the sternum, and also by a more extended origin, from the posterior moiety of the inferior surface of the coracoid; it is directed forwards, and is inserted by a short and strong tendon into the internal tuberosity of the humerus, which it depresses.

It is proportionally large in the Penguins and Gulls, but attains its greatest development in the Gallinaceous order.

Above the preceding muscle there is another longer and more slender one, analogous to the *Coraco-brachialis*, which arises from the middle of the posterior surface of the coracoid; its direction upwards is less vertical than that of the third pectoral, along the outer side of which it is attached to the anterior tuberosity of the humerus. This muscle is wanting in the *Struthionidæ*, is of small size in the Heron and Goose, is much more developed in the *Raptores* and many *Natatores*, especially the Penguins, and attains its greatest relative size in the *Rasores*, where it arises from almost the whole of the coracoideum.

Birds in general possess two *flexors* and one *extensor* (27) of the fore-arm, analogous to those which are found in the mammalia. They have also the muscles corresponding to the *pronators* and *supinators* of this higher class, but their action is limited in the feathered tribes to *inflexion* and *extension* of the fore-arm, and to *adduction* and *abduction* of the hand.

A remarkable muscle, partly analogous in its origin to the clavicular portion of the deltoid, but differently inserted, is called by Carus *Extensor plicæ alaris* (30, *a b*) and forms one of the most powerful flexors of the cubit. It is divided into two portions, of which the anterior and shorter arises from the internal tuberosity of the humerus; the posterior and longer from the clavicular extremity of the coracoid bone. In the *Ostrich* and *Rhea*, however, both portions arise from the coracoid. The posterior muscle (*b*) sends down a long and thin tendon which runs parallel with the humerus, and is inserted, generally by a bifurcate extremity, into both the radius and ulna. The anterior muscle (*a*) terminates in a small tendon, which runs along the edge of the aponeurotic expansion of the wing. In this situation it acquires exactly the structure and elasticity of the ligamentum subflavum or ligamentum nuchæ; it then resumes its ordinary tendinous structure, passes over the end of the radius, and is inserted into the style of the metacarpal bone. It combines with the preceding muscle in bending the fore-arm; and further, in consequence of the elasticity of its tendon, puckers up the soft part of the fold of the wing. (See 48, *fig.* 133.) An analogous structure is met with in the wing of the bat.

A lesser flexor of the fore-arm, and stretcher of the alar membrane (31) arises, as a portion of the serratus magnus from the ribs, and terminates in an aponeurosis inserted into the alar membrane and fascia of the fore-arm; it is represented in the figure as turned aside.

The *Extensor metacarpi radialis longus* (32) is the first muscle which detaches itself from the external condyle of the humerus (ε), and it forms the radial border of the muscular mass of the fore-arm; it terminates in a large tendon about the middle of the fore-arm, and this tendon passes along a groove of the radius, over the carpus, to the phalanx of the so called thumb, or spurious wing, into the radial margin of which it is inserted. It raises the hand, draws it forwards towards the radial margin of the fore-arm, and retains it in the same plane. In the Penguin this muscle is extremely feeble, and the tendon is lost in that of the *tensor plicæ alaris.*

The *Extensor metacarpi radialis brevis* (33) arises below the preceding from the ulnar edge of the radius, and is inserted into the phalanx of the thumb immediately beyond the tendon of the preceding muscle. The two tendons are quite distinct from one another in the Birds of Prey, the Ostrich and Parrots, but unite at the lower end of the fore-arm in the *Anatidæ*, *Phasianidæ*, and *Gruidæ*.

The muscle analogous to the *Extensor carpi ulnaris* (34) comes off from the inferior extremity of the outer condyle of the humerus, passes along the middle of the exterior surface of the fore-arm, and its tendon, after passing through a pulley at the distal end of the ulna, is inserted into the ulnar phalanx. It draws the hand towards the ulnar edge of the fore-arm, and is the principal abductor or folder of the pinion.

The *Flexor metacarpi radialis* (35) is a short and weak muscle, which arises from the inferior part of the ulna, descends along the internal side of that bone, winds round its lower extremity and the radial edge of the carpus, passes beneath the tendon of the radial extensors, and is inserted, external to the latter, high up into the dorsal aspect of the radial phalanx of the metacarpus. In the Ostrich it arises from the lower third of the ulna. In the Penguin it is wanting.

The *Flexor metacarpi ulnaris* (36) arises beneath the fore-arm from the internal pulley of the ulna, continues fleshy to the pinion, and is inserted, first into the ulnar carpal bone, then into the ulnar phalanx. The latter insertion is wanting both in the Ostrich and Penguin.

The *muscles* of the pinion or hand are few, and very distinct from one another; the thumb or spurious wing is moved by four small muscles, viz. two *extensors*, an *abductor*, which draws the thumb forwards, and an *adductor*. The second digit receives three short muscles, two of which are *extensors*, and the third an *abductor*, in this action it is aided by one and opposed by another of the extensors. The lesser digit receives an *abductor*, which comes from the ulnar edge of the preceding phalanx.

Muscles of the lower extremity.—Notwithstanding the simplicity of the motions of the lower or posterior extremity, the muscles of this part are numerous, and present several peculiarities in birds. The femur can be moved freely forward and backward, but its rotation is limited by a strong *ligamentum teres*, and the structure of the hip-joint does not permit it to be carried under the body, or far outwards.

In consequence of the form of the pelvis, the *psoas magnus* and *parvus*, the *obturator externus* and the *quadratus lumborum* do not exist in birds.

A large muscle, regarded by Cuvier as the *Obturator internus*, takes its origin from the internal surface of the ischio-pubic bone, it is directed from behind forwards, and gives off a strong and long tendon which passes through the small opening at the anterior part of the obturator foramen, which is situated between the *pubis* and *ischium*, (*f*, *fig.* 131.) In this situation a muscle, arising from the external border of the opening, attaches itself to the preceding, and is inserted conjointly with it into the posterior and outer aspect of the trochanter. Meckel compares this muscle with the *pectineus*, especially as it exists in the Saurian Reptiles, but observes that as it arises from both the internal and external surfaces of the circumference of the obturator foramen, it may represent both the internal and external obturator muscles. It is of an extraordinary size in the Ostrich.

The femur is raised by three muscles.

The most superficial and highest of these elevators (37) arises by a broad and thin aponeurosis from the anterior and external surface of the ilium, it is of a square form, descends almost in a straight line, and is inserted into the posterior part of the trochanter. Meckel regards it as analogous to the *Glutæus medius:* Carus calls it the *Glutæus maximus.* But the latter, according to Meckel, is represented by the posterior part of what Carus terms the *Rectus femoris latissimus* (40).

Anterior to the *Glutæus medius* of Meckel, there is a much smaller muscle, which extends from the anterior margin of the ilium to the trochanter, where it is inserted in front of the preceding. It is of an elongated quadrilateral form, and it represents the *Glutæus minor* of quadrupeds. It is wanting in many of the *Natatores*, and arrives at its greatest degree of development in the Raptorial Order.

A third muscle, still smaller and longer than the preceding and situated beneath it, which arises from the outer margin of the ilium, and is inserted into that part of the femur which corresponds to the lesser trochanter, is regarded by Meckel as the *Iliacus internus*, which Cuvier states to be wanting in Birds. It is, however, present in most, and is seen highly developed in the Ostrich.

The muscles analogous to the *Pyramidalis* and *Gemellus superior* exist in Birds.

There are most commonly three adductors of the thigh. The inferior, external, and posterior one arises from the middle of the external surface of the anterior margin of the ischio-pubic bone, and is inserted into the greater part of the lower half of the femur at 38.

The second and third *adductors* are situated internally to the preceding; the latter of these may be compared to the *Pectineus*.

The *Sartorius* (39) arises from the anterior point of the ilium, and passes down to be attached to the head of the tibia; it is an extensor of the leg upon the thigh.

The *Rectus femoris* (40) arises by a thin but wide aponeurosis from the spines of the sacrum, after a short course it joins the *Cruræus* and *Vasti* (42), and is inserted into the head of the fibula. It corresponds according to Meckel with the *Tensor vaginæ femoris* and the *Glutæus magnus*.

The *Gracilis* (41) arises from the superior part of the pubis, descends along the inner side of the thigh and towards the lower extremity of this part, is continued into a long and strong tendon, which passes in front of the knee-joint, and over the extensor tendon of the leg to the outer side of the fibula, whence it proceeds inwards, anterior to the tendon of the peroneal flexor, to become united to the outer origin of the flexor perforatus of the toes. Meckel considers that the muscle now described represents the *Rectus femoris* of mammalia, and regards as the *Gracilis* a small and thin muscle, whose origin has been transferred lower down, from the pubis to the femur, from the internal side of which it passes to the internal and superior part of the tibia. Be this as it may, the disposition of the former muscle is such, passing, viz. first, over the convexity of the knee-joint, and afterwards over the projection of the heel, that from its connection with a flexor of the toes, these must necessarily be bent simultaneously with every inflection of the joints of the knee and ankle. As these inflections naturally take place when the lower extremities yield to the superincumbent weight of the body, birds are thus enabled to grasp the twigs on which they rest whilst sleeping, without making any muscular exertion.

There are three *flexors* of the leg: one (43) which, although single, is from its insertion into the back of the fibula, analogous to the *Biceps flexor cruris* of the human subject: another on the inside is attached to the tendon of the extensors of the foot as well as the tibia; this muscle might be called the *Semimembranosus* (44): the third *flexor* is in the middle (45), it comes from the ischium, and as it descends it receives a broad fleshy slip from the back of the femur. It is inserted on the back of the tibia, the tendon covering those of the extensors of the heel.

The muscles of the feet present in Birds essential resemblances to the same parts in Reptiles. They are divided into muscles of the tarsus, of the metatarsus, and of the toes, the latter being subdivided into long and short. The principal points in which they differ from the same muscles in Reptiles and the Mammalia are the following: their origins and carneous portions are not situated on the foot but higher up on the tibia and even on the femur. The great length of the metatarsus occasions the smaller muscles to be of a greater proportional length than in other animals. The muscular portions are most developed in the *Raptores*, *Scansores*, and *Natatores*; the *Insessores* and *Rasores* present an intermediate proportion; the *Cursores* and *Grallatores* have the longest tendons.

The *Gastrocnemius* (46) has three distinct origins: two of these are superficial, one from the outer, the other from the inner condyle of the femur; the third origin is lower down from the inner side of the tibia and fibula (47). They unite to terminate in a thin and broad aponeurosis, which after becoming closely connected with a fibro-cartilage appertaining to the *flexor digitorum*, proceeds to be inserted into both the outer and inner margins of the tarso-metatarsal bone.

The *Tibialis anticus* (48) arises from the anterior part of the upper extremity of the tibia, below which its tendon passes through an aponeurotic loop extended from the outer to the inner margin of the tibia. It has also a second origin, by means of a slender tendon, from the anterior part of the external condyle of the femur. It is generally inserted pretty high up into the tarso-metatarsal bone between the outer and inner margins; but in the *Psittacidæ* it is attached lower down to the internal border, so as to turn the foot inwards as well as raise it, a disposition which is extremely favorable for the act of climbing.

The *Peroneus* (49) is a much smaller muscle: it extends from the lower region of the fibula, and the outer and anterior edge of the tibia to the tarso-metatarsal bone, into the outer side of the base of which it is inserted.

The *Flexor perforatus seu longus digitorum* (50) forms the superficial and external muscular mass of the leg: it arises by one mass from the posterior part of the external side of the femur, immediately in front of the outer head of the gastrocnemius; another portion arises from the outside of the lower extremity of the femur; these two heads unite below the middle of the leg and constitute one fleshy belly which gives off three tendons; these proceed to the proximal phalanges of the three outer toes where they bifurcate to give passage to the tendons of the *flexor perforans*.

The *Flexor pollicis* (51) arises, by its anterior head, from the anterior and upper part of the tibia, and by its posterior head from the external condyle of the femur; when it has reached the region of the calcaneum, it passes backwards through a synovial capsule, and is inserted into the proximal phalanx of the thumb, where it is perforated by the tendon of the *perforans* muscle.

The *Flexor profundus perforans* (52) arises as two distinct muscles, the one from the back of the femur and the other from the back of the tibia and fibula; the tendons of these two portions unite behind the metatarsal bone, and send off tendons to the last phalanges of the toes, which perforate those of the flexor sublimis.

The *Extensor longus communis digitorum* arises above from the anterior side of the tibia, below the tibialis anticus, passes beneath a strong restraining ligament, then lower down beneath an osseous bridge, and lastly across a strong ligament situated at the inferior extremity of the tarso-metatarsal bone. Below this part its tendon divides into three slips which are inserted into the distal phalanges of the three outer toes (53).

There are six long muscles lying on the metatarsal bone; they are largest and best marked in those birds which walk most, as the *Aves terrestres.* Two of these muscles are on the posterior surface; one goes to the base of the external toe, which it *abducts;* the other is inserted into the root of the back toe, which it *bends.* The other four muscles are on the anterior part of the metatarsus: the first extends the back toe; the second goes to the base of the first toe, and abducts it; the third is spread on the root of the middle toe, which it extends; the fourth lies along the outside of the metatarsus, perforates the end of the bone, and is implanted into the inside of the external toe, and abducts it.

Progression on land is generally effected in birds by the alternate advancement of the two feet; but sometimes they proceed by leaping or hopping, rather than walking; both feet are then firmly fixed on the ground, and the body is propelled forwards by a sudden extension of all the joints of the legs. Birds which have sharp claws, as the *Accipitres, &c.*, retract them when they hop, to prevent their being blunted. The *Cat tribe,* among mammalia, have a mechanism effecting a similar purpose. Some birds derive assistance in terrestrial progression by the flapping of the wings, and this is especially the case with the Ostrich, which runs by the alternate advancement of its legs.

The act of *climbing* is performed by means of a peculiar disposition of the toes, aided by prehension with the beak, as in the Maccaws and Parrots, or by the prop formed by the stiff tail-feathers, as in the Woodpeckers.

The act of *swimming* is rendered easy to birds by the specific levity of their body, arising from the extension of the air-cells; by the shape of the chest, which resembles the bottom of a boat; and by the conversion of the hinder extremities into oars in consequence of the membranes uniting the toes together. The effect of these web-feet in water is further assisted by the toes, having their membranes lying close together when carried forwards, whilst, on the contrary, they are expanded in striking backwards. The oar-like action of the hinder legs is still further favoured by their backward position; and by the metatarsus and toes being placed almost on the same perpendicular or vertical line with the tibia, an arrangement, however, which is unfavourable for walking.

Sailing.—Some birds, as the Swan, partially expand their wings to the wind while swimming, and thus move along the waters by means of sails as well as oars.

The act of *diving* is performed by the rapid and forcible action of the wings, beating the water as in flight, by the feet striking the waters backwards and upwards, and assisted probably by the compression of the air-cells.

Flight, the most important and characteristic mode of locomotion in birds, results principally from the construction and form of the anterior extremities, which have already been described. The form of the body has also especial reference to this power, the trunk being an oval with the large end forwards. The spine being short and inflexible, the muscles act to great advantage, and the centre of gravity is more easily changed from above the feet as in the stationary position, to between the wings as during flight. The head of the bird is generally small, and the beak pointed, which is a commodious form for dividing the air. The long and flexible neck compensates for the want of hands and the rigidity of the trunk, and contributes to change the centre of gravity, according to the required mode of progression, by simply projecting the head forwards, or drawing it back. The position of the great pectoral muscles, as before observed, always tends to keep the centre of gravity at the inferior part of the body. The power which birds enjoy of raising and supporting themselves in the air is undoubtedly aided by the lightness of the body. The large cavities in the bones diminish their weight without taking away from their strength,—a hollow cylinder being stronger than a solid one of the same weight and length. But the specific levity principally depends on the great air-cells, which occupy almost every part of the body, and which are all in communication with the lungs. The air which birds inspire distends these cells, being expanded by the great heat of the body. Lastly, the feathers, and especially the quills, from their lightness and elastic firmness, contribute powerfully to the act of flying by the great extent which they give to the wings, the length and breadth of which are further increased by the expanded integument situated in the bend of the arm and in the axilla.

When a bird commences its flight it springs into the air, either leaping from the ground, or precipitating itself from some elevated point. During this action it raises the humerus, and with it the entire wing, as yet unfolded; it next spreads it horizontally by an extension or adduction of the fore-arm and hand; the greatest extent of surface of the wing being thus acquired, it is rapidly and forcibly depressed; the resistance of the air thus suddenly struck occasions a reaction on the body of the bird, which is thereby raised in the same manner as in leaping from the ground. The impulse being once given, the bird folds the wings by bending the different joints, and raises it preparatory to another stroke.

Velocity of flight depends upon the rapidity with which the strokes of the wings succeed each other. A simple downward stroke would only tend to raise the bird in the air; to carry it forwards the wings require to be moved in an oblique plane, so as to strike backwards as well as downwards. The turning in flight to the right or to the left is principally effected by an inequality in the vibrations of the wings. To wheel to the right the left wing must be plied with greater frequency or force, and *vice versâ.*

The outspread tail contributes to sustain the posterior part of the body; when depressed during a rapid forward flight, the anterior part of the body is raised, and flight retarded; when the tail is raised the anterior part of the body is lowered. Some birds bend the tail to one side, using it as a rudder when the horizontal course of flight is required to be changed.

The first launch of the bird into the air is produced by an ordinary leap from the ground, and depends, in some degree, on the length of the legs. Those birds which have very short legs and very long wings, as the *Swallows*, &c., cannot leap high enough to gain the requisite space for the expansion of their wings, and consequently have much difficulty in raising themselves from the ground, and generally prefer throwing themselves from some high point. The manner of flight varies exceedingly in different birds, some dart forward by jerks, closing their wings every three or four strokes; the Woodpeckers, Wagtails, and most of the small *Insessores* are characterized by this kind of undulatory motion: other birds, as the Swallow, Crow, &c. fly smooth and even: the Kite and Kestrel Hawk and the great Albatross sometimes appear to buoy themselves in the air without any perceptible motion of the wings.

The rapidity with which a strong Bird of Prey flies in pursuit of his quarry is inconceivably great. The anecdote of the Falcon belonging to Henry IV. King of France, which flew in one day from Fontainbleau to Malta, a distance of 1350 miles, is well known, and many similar instances are on record. The flight of a Hawk, when its powers are fully exerted, is calculated at one hundred and fifty miles an hour. The Eider-Duck's usual flight has been ascertained to be at the rate of ninety miles an hour.

The famous Race-horse Eclipse is said to have gone at the rate of a mile in a minute for a very short distance; but this speed, if it could be continued, would not be half so great as that which many birds put in practice during their long journeys of migration.

Of the Nervous System.—There is a remarkable uniformity in the form and structure of the brain (*fig.* 134, *a, b, c, d*) and medulla spinalis (*e, e*) in the different orders of birds. These great divisions of the cerebro-spinal axis are always readily distinguishable from one another by the greater breadth and globular form of the brain, which is proportionally much larger than in the other oviparous vertebrata. The high degree of development which the spinal cord and cerebellum present, as compared with the cold-blooded Reptilia, has an evident relation to the extraordinary locomotive powers with which the feathered class is endowed.

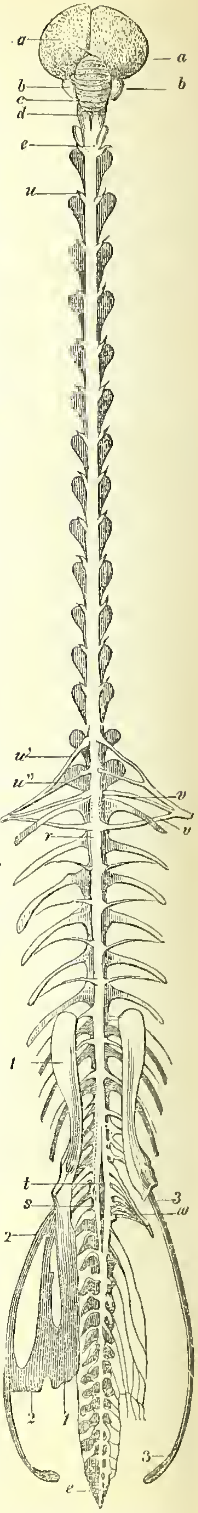
In a Pigeon weighing eight ounces with, and seven ounces without its feathers, or three thousand three hundred and sixty grains, the cerebro-spinal axis weighs forty-eight grains, the weight of the spinal cord being eleven, and that of the brain thirty-seven grains.

Of the Brain.—The brain of the bird differs from that of the reptile in the superior size of the cerebrum, and the more complex structure of the cerebellum; it differs from the brain of a mammal in the smaller size of the cerebellum, resulting from the want of the lateral lobes, and in the absence or rudimentary condition of the fornix; and it differs from the brain of every other vertebrate class in the lateral and inferior position of the optic lobes or bigeminal bodies.*

It cannot be at once distinguished, as Cuvier asserts, by being composed of six outward and visible masses, since the two hemispheres, (*a, a,*) the two optic lobes, (*b, b,*) the cerebellum, (*c,*) and medulla oblongata, (*d,*)

* We have lately ascertained that the corpus callosum is wanting in some of the marsupial animals; its presence is therefore no longer characteristic of the class mammalia.

(*Fig.* 134.)

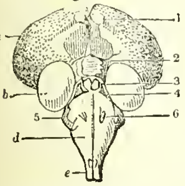


Brain and Spinal Cord of a Goose.

are equally obvious in the brains of reptiles. They are, however, differently disposed in birds; the optic lobes, which in reptiles intervene and are visible between the cerebrum and cerebellum, being in birds displaced, as it were, by the hemisphere and cerebellum coming into close contact, so that the optic lobes are pushed downwards and to one side. The transverse convolutions of the cerebellum at once distinguish, however, the brain of a bird from that of any reptile and most fishes; but it is a curious fact that the cerebellum in the sharks is similarly composed of a vermiform process only, transversely folded or convoluted.

The cerebral hemispheres sometimes present the form of a flattened oval, as in the Parrot tribe, but in general are of a convex cordiform shape, with the apex directed forward.

Fig. 135.



Base of the brain of a Pigeon.

The optic lobes (*b*, *fig*. 135) are rounded tubercles, situated below and behind the hemispheres, in the lateral interspace between these and the cerebellum.

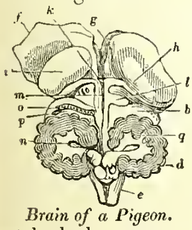
The cerebellum is composed of the middle lobe only, and is of a compressed arched form.

The medulla oblongata presents neither a tuber annulare nor corpora olivaria or pyramidalia, but is a large uniform tract situated between and behind the optie lobes.

On the lower part of the side of each eerebral hemisphere there is a depression which corresponds to the fissura magna Sylvii, and is the only appearance which the hemispheres present of a division into lobes. Elsewhere there are no traces of convolutions, the cerebrum in this respect resembling that of Reptiles and Fishes, and some of the least intelligent orders of Mammalia, as the *Rodentia*, *Marsupiata*, and *Edentata*. The optic lobes are also devoid of the transverse fissure which bisects the optic lobes of mammalia.

The cerebellum is marked by close and transverse anfractuosities, such as characterize the corresponding portion of the cerebellum in mammalia, called the vermiform process.

Fig. 136.



Brain of a Pigeon.

When the cerebral hemispheres are divaricated from each other, (*fig*. 136,) they are seen to be disunited through the whole of their vertical extent, and to be joined only by the round anterior commissure of the brain (*k*, *fig*. 136.) In fact both the corpus callosum and fornix are wanting; or at most a rudiment only of the latter part can be perceived in the brains of some birds, as the Eagles, Vultures, and Parrots. The mesial surfaces of the hemispheres, which are in contact with each other, present a few striæ which diverge from the commissure. These surfaces are composed of an extremely thin layer of medullary substanee, (*g*,) forming the internal parietes of the ventricle, and extended outwardly over the corpus striatum (*i*.) This body is of very great size in birds, constituting of itself almost the entire substance of the hemisphere, projecting into the ventricle, (*h*,) not only from below, but from the anterior and outer sides of the cavity, and being covered by a smooth layer or fold of medullary matter, (*f*,) which increases in thickness anteriorly. The ventricle does not extend below the corpus striatum to form an inferior horn; and, as in most mammalia there is no extension of the cavity backwards to form a posterior horn, there is consequently no *cornu ammonis*. The vessel forming the plexus choroides penetrates the ventricle beneath the posterior part of the thin internal wall, and the lateral ventricles communicate together there, and with the third ventricle. They are continued anteriorly to the root of the olfactory nerve, which is itself a continuation of the apex of the hemisphere.

Just above the orifice of communication there is a smooth flattened projection, rounded externally, which advances into the ventricle from the internal wall; this is a rudiment of the fornix.

The round anterior commissure (*k*) is prolonged on either side into the substance of the hemispheres, as in man and quadrupeds.

The optic thalami (*l*) are of small size, and not united by a soft commissure: between them is the cavity called third ventricle (*m*); and above and behind they give off the peduncles of the pineal gland. This body does not hang freely suspended by the pedicles, but seems to form a rounded and thickened anterior border of the valvula Vieussenii or lamelliform commissure of the optic lobes. Carus describes the pineal gland as adhering firmly to the confluence of the great veins situated at the anterior orifice of the aqueduct of Sylvius. In Pigeons he states that it is composed of many segments, but that in general it is of a simple and conical form; the figure which he gives of it, from the Turkey, exhibits a pyriform shape.* The valve which closes the upper part of the passage from the third to the fourth ventricle, is a thin lamella of great width, in consequence of the distance to which the optic lobes are separated from one another. Anteriorly the third ventricle communicates with the infundibulum.

The fourth ventricle (*n*) resembles that in the brain in mammalia, but is of less width; its floor is indented with the longitudinal fissure called *calamus scriptorius*.

Besides the cavities or ventricles above mentioned, there are also two others situated in the optic lobes (*o*), or bigeminal bodies, each of whieh, when laid open, is seen to be occupied by a convex body (*p*) projecting from the posterior and internal side of the lobe; these ventricles communicate with the others in the aqueduct of Sylvius.

As there is no transverse furrow in the optie lobes, they cannot be distinguished into the protuberanees called 'nates' and 'testes' in

* Anat. Comparée, nouv. ed. i. p. 88, pl. xv. fig. 6.

the human brain; they have most resemblance, however, to the latter bodies.

With respect to the substance of which the brain of birds is composed, we may observe that the bodies analogous to the *corpora striata* do not merit that name, as there are no alternating striæ of grey and white matter. In this respect the bird's brain resembles that of the cold-blooded ovipara and of the human fœtus. The substance of the cerebellum does present the admixture of the two substances, or *arbor vitæ (q)*, but in a less complicated degree than in mammalia.

The brain in birds is invested with the same membranes as are described in Mammalia.

Medulla spinalis.—The spinal cord is continued from the foramen magnum to the canal formed by the coccygeal vertebræ, where, however, it becomes extremely attenuated, and corresponds in extent to the shortness of that division of the vertebral column, terminating in a mere filament which expends itself in distributing a few pairs of nerves through the coccygeal foramina. As in the Mammalia, it appears externally to be composed of the white or medullary matter, but contains a small proportion of grey substance internally. It is of a cylindrical figure, and as in the cold-blooded ovipara, it is of great length in proportion to the brain. An *anterior* and *posterior* fissure may be distinguished, and also a narrow canal which extends through its entire length. Two enlargements occur in the course of the spinal cord, one corresponding to the wings, the other to the legs; and from these swellings the nerves of the brachial and sacral plexuses come off respectively. As might be expected, therefore, these enlargements present differences of relative size corresponding to the different relative development and powers of the anterior and posterior extremities. In general the posterior enlargement is greater than the anterior; and this difference is very remarkable in the Struthious birds in which the whole business of progression falls upon the posterior extremities.

Besides the difference in size, the spinal enlargements or ganglions, as they may be termed, differ also in structure; at the anterior, alar, or thoracic enlargement *(r, fig.* 134) the spinal cord merely receives an accession of grey and white medullary substance; but at the beginning of the sacral swelling *(s, fig.* 134) the canal of the cord enlarges in a remarkable manner, so that the lateral cords separate from one another posteriorly or above, precisely as they do to form the fourth cerebral ventricle: the cavity or spinal ventricle *(s, fig.* 134) thus formed, is filled with a serous fluid inclosed in a pia mater. From the figure of this cavity it has been termed the '*Sinus rhomboidalis.*'

Of the Nerves.—The cerebral nerves correspond in number to those of the Mammalia. The principal difference of form and structure is presented in the *olfactory* or *first* pair (1, *fig.* 135.) These nerves are of a cylindrical figure and small extent, being continued from the anterior extremity or apex of the hemispheres. Instead of separating into filaments to pass out of the skull by a cribriform lamella, each nerve is continued along an osseous canal, accompanied by a venous trunk, as far as the pituitary membrane of the superior spongy bone upon which its filaments are distributed in a radiated manner.

The optic nerves (2, *figs.* 135, 137,) are in general of remarkable size; they arise from the whole of the outer surface of the optic lobes, and form in front of the infundibulum, a perfect union, or *chiasma*, (2*, *fig.* 137,) in which, on making a horizontal section, some transverse striæ may be perceived, apparently resulting from the decussating fibrils of the nerves.

The distribution of the *third*, (3, *figs.* 135, 137,) *fourth*, (4, *figs.* 135, 137,) and *sixth* cerebral nerves, (6, *figs.* 135, 137,) is almost the same as in Mammalia. The course of the fourth pair, immediately above the supra-orbital branch of the fifth pair is shown at 4*, *fig.* 137, as far as its termination in the superior oblique muscle to which it is, as in other vertebrata, exclusively distributed.

The *fifth* or trigeminal nerve (5, *figs.* 135, 137) has nearly the same distribution as in Mammalia.

The first or *ophthalmic* division (5*, *fig.* 137) passes out of the cranium by a peculiar canal situated externally to the optic foramen. It is of large size, and describes in its passage through the orbit a curve corresponding to the roof of that cavity; it generally penetrates the substance of the facial bones above the nasal fossæ. It divides into three branches; the *first* or superior is the smallest and is lost upon the pituitary membrane; the *second* branch is the largest of the three and the longest; it is received into an osseous canal, passes over the nasal organs, and terminates at the extremity of the beak in a great number of divisions; the *third* branch of the ophthalmic nerve is entirely distributed to the skin which covers the circumference of the external nostrils.

The second division, or *superior maxillary* nerve passes out of the same foramen as the *inferior* one (at 5″, *fig.* 137,) immediately above the tympanic bone or *os quadratum;* it passes forwards along the floor of the orbit, and in this part of its course gives off two filaments, of which one joins the ramifications of the ophthalmic nerve, the other ascends, penetrates the substance of the pterygoid muscles and the maxillary bone, to be lost on the lateral parts of the bill. In those birds, as the *Anatidæ* and other Water-fowl, where the upper mandible is notched on the edge, each denticulation receives four or five nervous filaments, and the nerve is proportionally of large size.

The *inferior maxillary nerve* separates from the superior, and proceeds obliquely downwards, dispensing branches to the pterygoid and quadrangular muscles of the jaws; the trunk proceeds outwards to the lower jaw where it divides into two branches an internal and an external. The internal, which is a continuation of the trunk, penetrates the maxillary canal, and is continued to the anterior end of that mandible. In the *Anatidæ* it gives off nerves to the dentations along the edge of the mandible. The external branch recedes from the internal, perforates the jaw, and is distributed on its external surface beneath the tegumentary or horny substance which sheaths the extremity of the mandible. It supplies no gustatory branch to the tongue, which is an organ of prehension, not of taste, in Birds.

The *facial nerve*, or portio dura, exists in Birds, but it is extremely small, its offices being hardly required, in consequence of the structure of the parts of the face in this class. However, a few branches may, with difficulty indeed, be traced, and the trunk of the nerve is constantly present.

The *auditory nerve*, or portio mollis, is large, very soft and pulpy, and of reddish colour; it is received into a deep depression on the internal surface of the cranium (at 7, *fig.* 137), whence it penetrates by several small foramina to the labyrinth.

The *pneumogastric nerve*, or *nervus vagus*, generally passes out of the cranium in two or three filaments, which afterwards rejoin. On leaving the skull, this nerve communicates with the lingual and glosso-pharyngeal nerves. and is situated between them, the lingual being placed in front. Each nerve of the *par vagum* passes as a distinct strong cord along the neck in company with the jugular vein, and descending into the chest forms the cardiac and pulmonary plexuses, as in Mammalia. The two nerves unite behind the heart, and proceed along the œsophagus to terminate in anastomoses with the great sympathetic nerve.

The *glosso-pharyngeal* nerve of the eighth pair passes out of the cranium through the foramen behind the ear, which corresponds to the *foramen lacerum posterius*, by two filaments, which immediately unite to form an elongated quadrangular ganglion; this sends off a small internal branch in front of the muscles of the neck; a small posterior twig which unites with the par vagum, and a large inferior branch to the anterior part of the neck. The latter is a continuation of the nerve itself; it descends along the œsophagus and divides into two principal branches, of which one passes upwards to the muscles of the os hyoides, between which it is included, and this branch is remarkably tortuous in the Woodpecker in order to be accommodated to the extensile motions of the tongue. The other branch descends along the lateral parietes of the œsophagus, and sends off a twig to join the lingual nerve. The termination of the glosso-pharyngeal is expanded upon the œsophagus.

The *hypoglossal* nerve (9th pair) escapes from the cranium posterior to the nervus vagus by the condyloid foramen. It is very slender at its origin; passes to the front of the nervus vagus, partly uniting with, as it crosses over this nerve, and in that situation it detaches a small filament analogous to the *descendens noni*, which accompanies the jugular vein to the chest. The trunk of the hypoglossal next crosses the glosso-pharyngeal nerve, then passes beneath the cornu of the os hyoides, and advances towards the superior larynx, where it terminates by dividing into two principal branches, which are distributed, the one to the anterior and inferior, the other to the superior and internal parts, of the tongue.

Spinal nerves.—These correspond in number to the vertebræ of the spine. They arise, as in the other vertebrata by two roots, the ganglion on the posterior of which is proportionally very large. In the sacral region of the spine, the anterior and posterior roots escape by distinct foramina, and can be separately divided without laying open the bony canal, but they are deeply seated and well protected by the anchylosed processes of the sacrum and the extended iliac bones.

The *cervical* nerves vary considerably in number, the known extremes being from ten to twenty-three, corresponding to the number of vertebræ. They are proportionally larger than in man, are tortuous in their course, to be accommodated to the extensive motions of the neck, and are principally lost in the integument. Only the last, or last two, pairs (*u' u''*, *fig.* 134) of cervical nerves concur in the formation of the brachial plexus, which is completed by the first two pairs of dorsal or thoracic nerves (*v*).

The *dorsal* nerves do not present any notable differences from those of mammalia.

The *sacral* nerves have no other peculiarity than their mode of passing out of the spinal canal: they form exclusively the plexus analogous to the lumbar and sacral (*w*, *fig.* 134).

The nerve analogous to the phrenic nerve is wanting in Birds, in correspondence with the rudimentary condition of the diaphragm.

The *brachial plexus*, formed by the two last cervical and one or two first dorsal nerves, soon becomes blended into a single fasciculus whence all the nerves of the wing are derived. According to Cuvier, the first four that are given off are of large size, and are distributed to the great and middle pectoral and subclavian muscles. A small filament is then detached which supplies the muscles surrounding the head of the humerus and capsule of the joint; this represents the articular nerve. The rest of the plexus divides into two large nerves, which supply the wing.

Macartney describes the course of the *nerves of the wing* in a somewhat different manner, and observes that they more nearly resemble those of the superior extremity in mammalia, than Cuvier has represented. The brachial plexus, according to this author, gives rise to three nerves which are distributed in the following manner:—"The first is a very fine filament, which runs down on the inside of the arm, and is lost about the internal part of the elbow. This is analogous to the *internal cutaneous* nerve. The second is a large cord; it gives off a very large branch, which divides into many others, for the supply of the pectoral muscles; it sends several smaller branches to the muscles under the clavicle and about the joint, and then proceeds to the inner edge of the biceps muscle, along which it descends to the fold of the arm, after giving some large muscular branches. Before it reaches the joint, it divides into two branches; one of which is analogous to the *ulnar* nerve, and the other soon divides again into nerves which are similar to the *median* and *musculo-cutaneous*. The *median* dips down amongst the muscles on the middle of the fore-arm, to which it gives branches, and afterwards runs along the inter-osseous space, passes under the annular ligament of the carpus, and is distributed to the short muscles of the digiti. The branch analogous to the musculo-cutaneous nerve, is expanded upon the muscles on the upper edge of the radius.

"The *ulnar* nerve, although it appears to be incorporated with the *median* on the upper arm, can be easily separated from it, and traced to its proper origin in the brachial plexus. After this nerve leaves the median, it turns over the end of the foramen to get upon the edge of the ulna. It gives filaments to the muscles in this situation; but its chief branch runs down superficially upon the ligaments of the quills in company with a vein, and goes ultimately to be lost upon the ulnar edge of the hand.

"The third cord furnished by the brachial plexus, supplies the place of the *radial* nerve. It detaches several filaments to the muscles on the inside and back of the scapula. It gives off also the *articular nerve*, and then winds round the humerus between the extensor muscles, to which it furnishes some large filaments. On coming to the outside of the humerus, it sends a branch between the integuments of the fold of the wing. The nerve now turns round the neck of the radius, beneath the muscles, and forms two branches; of which one passes under the muscles to the outer side of the ulna, along which it runs superficially to the hand; the other branch passes on the radial side, but more deeply amongst the muscles, goes under the annular ligament of the carpus, proceeds between the branches of the metacarpus, and is finally lost on the back of the digiti." The same anatomist describes the course of the nerves of the posterior extremities as follows.

"Although Cuvier has given a more accurate description of the nerves of the lower extremity than those of the wing, it nevertheless needs correction in several particulars.

"The *obturator* and *femoral* nerves arise from the same plexus which is formed by the two last lumbar nerves, by a communicating branch from the first sacral pair. The obturator nerve passes through the upper part of the foramen ovale, and is distributed to the muscles around the hip-joint, especially the adductor. The femoral nerve passes out of the pelvis in company with the artery, over the upper edge of the ilium. It divides into three branches, which are dispersed among the muscles and integuments on the anterior and inner part of the thigh. Some of these filaments are long, and descend superficially for a considerable way upon the limb.

"The ischiatic nerve is composed of the five superior sacral nerves; and as soon as it departs from the plexus, even within the pelvis, is easily separable into its primary branches. Immediately after it passes through the ischiadic foramen, it sends filaments to the muscles on the outer part of the thigh; it then proceeds under the biceps muscle, along the back of the thigh, about the middle of which it becomes divided into the *tibial* and the *peroneal* nerves.

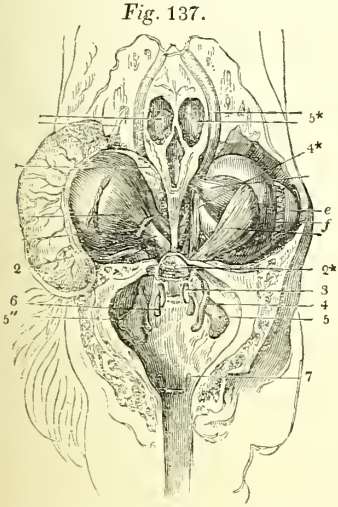
"The *tibial* nerve, even before it arrives in the ham, separates into several branches, which pass on each side of the bloodvessels, and are chiefly distributed to the muscles on the back of the leg. Two of these branches, however, are differently disposed of; the one accompanies the posterior tibial artery down the leg, passes over the internal part of the pulley, and is lost in small filaments and anastomoses, with a branch of the peroneal nerve on the inner side of the metatarsus; the other branch runs down on the peroneal side of the leg, along the deep-seated flexors of the toes, passes in a sheath formed for it on the outer edge of the moveable pulley of the heel, and proceeds under the flexor tendons along the metatarsal bone, to be distributed to the internal part of the two external toes.

"The peroneal nerve is directed to the outer part of the leg; it dips above the gastrocnemii muscles, and runs through the same ligamentous pulley that transmits the tendon of the biceps muscle; it then detaches some large filaments to the muscles on the anterior part of the leg, under which it divides into two branches, which proceed close together, in company with the anterior tibial artery to the fore part of the ankle-joint, at which place they separate; one passes superficially over the outer part of the joint, the other goes first under the transverse ligament which binds down the tendon of the tibialis anticus muscle on the tibia, and then over the inner part of the joint, below which it divides into two branches, the one is distributed to the inner side of the metatarsus and the tibial side of the pollex, and to the next toe; the other turns towards the centre of the metatarsal bone, and penetrates the tendon of the tibialis anticus just at its insertion, and then rejoins the branch of the peroneal nerve it accompanied down the leg. They continue their course together again in the anterior furrow of the metatarsal bone; and at the root of the toes, separate once more, and proceed to the interspaces of the three anterior toes, and each divides into two filaments, which run along the sides of the toes to the nail."—*Rees' Cyclopædia, Art. Birds.*

The *great sympathetic nerve* of birds resembles, in many particulars, that of mammals. It enters the cranium by the same orifice as that by which the nervus vagus and the glosso-pharyngeal make their exit; it there unites with the fifth and sixth pair of nerves. At the base of the cranium the first ganglion, or superior cervical, is of a lenticular form, and communicates at once with the ninth and eighth pairs of nerves, so as to seem as if it were blended with them. The remainder of the chain of cervical ganglions are very remarkably situated, being lodged on either side in the canal of the vertebral artery formed by the transverse processes; into which it passes, or from which it escapes above, at the third cervical vertebra, while below the sympathetic again becomes conspicuous at the commencement of the thorax, where it sends a considerable branch from the first thoracic ganglion to join the pulmonary plexus formed by the par vagum. This ganglion also distributes seven other filaments, one of which goes to join the brachial plexus; a second is lost in the cardiac plexus of the par vagum; three other filaments proceed inwardly to the projection formed by the bodies of the vertebræ to produce the commencement of the splanchnic nerve; lastly, the sixth and seventh serve to unite the first ganglion with the second, one passing above, the other below the head of the rib, which they thus include in a lozenge-shaped space. Each of the succeeding ganglions forms, in like manner, a centre of nervous radiations, which are five, six, or seven in number, of which four, two anterior and two posterior, serve to bring the contiguous ganglia into communication with each other; one or two contribute to the formation of the splanchnic nerve, and one joins the dorsal spinal nerve situated immediately behind the ganglion.

The splanchnic nerves, formed by all the internal thoracic branches of the great intercostal, accompany on either side the trunk of the aorta. When it has arrived at the cœliac axis, they surround it and form one, two, or three ganglions from which an immense number of filaments are thrown off, which surround the different arteries of the abdomen. These ganglions are evidently the analogues of the semilunar ganglions of man, and the filaments proceeding from them correspond to the solar plexus. The trunk of the sympathetic continues along the bodies of the vertebræ, but the ganglions become less marked after the ribs cease to be given off; two or three filaments are given off from each of these small swellings, which, by uniting with the filaments of the opposite side, form a plexus around the aorta. The termination of the sympathetic may be readily traced along the coccyx, where four pairs of ganglions are observable in the Swan, the last of which join to form a *ganglion impar*.

Fig. 137.



Cerebral nerves, eyes, &c. in situ of a Goose.

Organs of Vision.—The eye in Birds presents many peculiarities, which chiefly relate to the extraordinary powers of locomotion in this class, tending to accommodate vision to a rapid change of distance in the objects viewed, and to facilitate their distinct perception through a rare medium.

There is no species of bird in which the eyes are wanting, or are rudimentary, as occurs in the other vertebrate classes.

The eyes of Birds are, in the first place, remarkable for their great *size*, both as compared with the brain and with the entire head, (*fig.* 137,) being analogous, in this respect, to the eyes of some of the flying insects. Their *form* is admirably adapted to promote the objects above named. The anterior segment of the eye is more prominent than in any other class of animals, and is in many birds prolonged into a tubular form, terminated by a very convex cornea (*e, fig.* 137.) Dr. Macartney observes that " the owl furnishes the most striking example of the disproportion between the anterior and posterior spheres of the eye, the axis of the anterior portion being twice as great as that of the other. The obvious consequence of this figure of the globe of the eye is to allow room for a greater proportion of aqueous fluid, and for the removal of the chrystalline lens from the seat of the sensation, and thus produce a greater convergence of the rays of light, by which the animal is enabled to discern the objects placed near it, and to see with a weaker light; and hence *owls*, which require this sort of vision so much, possess the structure fitted to effect it in so remarkable a degree."

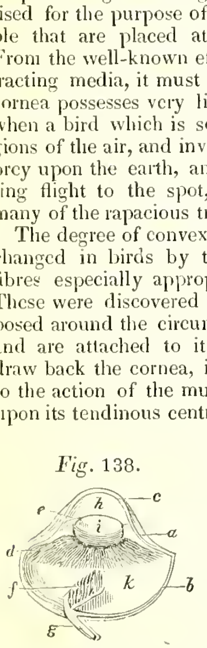
The anterior division of the eye is least convex in the swimming birds. The sclerotic coat is divisible into three layers. It is thin, flexible, and somewhat elastic posteriorly, where it presents a bluish shining appearance, without any distinct fibres, but anteriorly its form is maintained by a circle of osseous plates or scales (*f, fig.* 137) interposed between the exterior and middle layers. These plates vary from thirteen to twenty in number, and are situated immediately behind the cornea, with their edges overlapping each other. They are in general thin, and of an oblong quadrate figure, becoming elongated from before backwards in proportion as the bird possesses the power of changing the convexity of the cornea. In the nocturnal *Raptores* the bony plates are strong and thick, and extend from the cornea over the whole of the anterior projecting division of the eye to the posterior hemisphere, which they also contribute to form. The figure of the eye is thus maintained, notwithstanding its want of sphericity; and in other classes, as Reptiles and Fishes, where the eye recedes from the spherical figure from an opposite cause, viz. the extreme flattening of the cornea, that form is also preserved by the introduction of an osseous structure in the sclerotic.

The bony plates are capable of a degree of motion upon each other, which is, however, restrained within certain limits by the attachments of their anterior and posterior edges to the sclerotic coat; and by their being bound together with a tough ligamentous substanec, which seems to be the continuation of the selerotic between the edges that overlap each other.

The *cornea* possesses the same structure as in mammalia, but differs with respeet to form. When the posterior part of the eye is eompressed by the muscles, the humours are urged forwards and distend the cornea; which, at that time, becomes much more prominent in most birds than it is ever observed in mammalia; and under such circumstances, the eye is in a state for pereeiving near objects. When the muscles are quite relaxed, the contents of the eye-ball retire to the posterior part, and the cornea beeomes flat or even depressed: this is the condition in whieh we always find the eye of a dead bird, but we can have no opportunity of perceiving it during life. It is only practised for the purpose of rendering objects visible that are placed at an extreme distance. From the well-known effects of form upon refracting media, it must be presumed, that the cornea possesses very little, if any, convexity, when a bird which is soaring in the higher regions of the air, and invisible to us, discerns its prey upon the earth, and deseends with unerring flight to the spot, as is customary with many of the rapacious tribe.

The degree of convexity of the eornea is also changed in birds by the aetion of muscular fibres especially appropriated to its motions. These were discovered by Crampton; are disposed around the circumference of the cornea, and are attached to its internal layer; they draw back the cornea, in a manner analogous to the action of the muscles of the diaphragm upon its tendinous centre.

Fig. 138.



The *choroid coat* resembles in its structure that of mammalia; it is copiously covered with a black pigment, similar to that in the human eye. Opposite the bony circle the choroid separates into two layers; the external layer is the thinnest, and adheres at first firmly to the sclerotica, after which it is produced freely inwards to form, or be continuous with, the iris.

The *iris* (*c*, *fig.* 138) is delicate in its texture, which under the lens appears composed of a fine net-work of interlacing fibres, but it is remarkable for the activity and extent of its movements, which seem in many birds to be voluntary. The contraction and dilatation of the pupil, independent of any change in the quantity of light to which the eye is exposed, is most conspicuous and remarkable in the Parrot tribe, but we have observed it also in the Cassowary and some other birds.

The colour of the iris is subject to many varieties, which frequently display great brilliancy, and afford zoologists distinguishing specific characters of birds; although these cannot always be implicitly relied upon.

The breadth of the iris varies in different species, but is greatest in Birds whieh take their food in the gloom of evening, as the Owls and Night-jar, in order that the pupil may be proportionally enlarged to admit as much light as possible to the retina. Carus observes that in the eye of the Owl is exhibited with peculiar distinetness the remarkable distribution of the ciliary nerves and vessels, which, running in the form of single trunks between the choroid and sclerotica, terminate anteriorly in several ring-shaped plexuses for the supply of the iris and of the muscular circle of the cornea. The pupil is usually round: in the Goose and Dove it is elongated transversely, and in the Owls is vertically oval.

The inner layer of the choroid is thicker than the external, and is disposed in numerous thickly set plicæ radiating towards the anterior part of the chrystalline lens, where they terminate in slightly projecting *ciliary processes*, (*d*, *fig.* 138,) the extremities of which adhere firmly to the capsule of the chrystalline. These processes are the most numerous, close set, and delicate in the Owl; they are proportionally larger and looser in the Ostrich.

The chief peculiarity in the eye of the Bird is the *marsupium* or *pecten*, (*f*, *fig.* 138,) which is a plicated vascular membrane analogous in structure to the choroid, and equally blackened by the pigmentum; situated in the vitreous humour anterior to the retina, and extending from the point where the optie nerve penetrates the eye to a greater or less distance forwards, being in many birds attached to the posterior part of the capsule of the chrystalline. As its posterior point of attachment is not to the choroid but to the termination of the optic nerve, this requires to be first described.

When the optic nerve arrives at the sclerotic, it tapers into a long conical extremity, which glides into a sheath of a corresponding figure, excavated in the substance of that membrane, and directed downwards and obliquely forwards. The central or inner layer of this sheath is split longitudinally, and the substance of the nerves passes through this fissure. A similar but longer fissure exists in the corresponding part of the choroid: so that the extremity of the optic nerve presents in the interior of the eye, instead of a round disc, as in mammalia, a white narrow streak, from the extremities and sides of which the retina is continued. Branches of the ophthalmic artery, which are quite distinct from the vessels of the choroid, and analogous to the *arteria centralis retinæ*, enter the eye between the laminæ of the retina, along the whole extent of the oblique slit above mentioned, and immediately enter or compose the folds of the marsupial membrane, upon which they form most delicate and beautiful arborescent ramifications.

The marsupium is lodged like a wedge in the substance of the vitreous humour, in a vertical plane, directed obliquely forwards. In those species in which the marsupium is widest, the angle next the cornea reaches the inferior edge of the capsule of the chrystalline; but where it is narrow, the whole anterior surface is in contact with the same point. This contaet is so close in some birds, as the Vulture, Parrot, Turkey, Cassowary, Stork, Goose, and Swan, that the marsupium seems absolutely to adhere to the capsule of the lens; but in many other birds, on the contrary, it does not extend further than two thirds of the distance from the back part of the eye, and is attached at its anterior extremity to some of the numerous laminæ of the hyaloid membrane which form the cells for the lodgment of the vitreous humour. In these cases the marsupium can have no influence on the movements of the lens, unless it be endowed with an erectile property, and be so far extended as to push forward the lens. The researches of Bauer* have shewn that there is no muscular structure in the marsupium, and its changes of form, if such occur in the living bird, must be effected by changes in the condition of the vessels of which it is almost exclusively composed.

The form of the marsupium varies in different birds; it is broader than it is long in the Stork, Heron, Turkey, and Swan; and of the contrary dimensions in the Owl, Ostrich, and Cassowary. The plicæ of the membrane are perpendicular to the terminal line of the optic nerve; they are of a rounded figure in most species, but in the Ostrich and Cassowary they are compressed, and so far inclined from the plane of the membrane, that their convergence towards its extremity gives it a resemblance to a close-drawn purse.† The folds vary in number, being four in the Cassowary, seven in the Great Horned Owl, eight in the Goose, from ten to twelve in the Duck and Vulture, fifteen in the Ostrich, sixteen in the Stork, and still more numerous in the Insessorial Birds, amounting to twenty-eight, according to Soemmerring, in the Fieldfare.

The exact functions of the marsupial membrane are still involved in obscurity. Its position is such that some of the rays of light proceeding from objects laterally situated with respect to the eye must fall upon and be absorbed by it; and Petit accordingly supposed that it contributed to render more distinct the perception of objects placed in front of the eye. The theory originally proposed by Sir Everard Home,‡ which attributed to the marsupium the office of retracting the lens for the purpose of distant vision by its muscular contraction, is opposed by the numerous examples in which it does not extend to the chrystalline, and by the manner of its attachment in those cases in which it does; since, as in these the marsupium adheres to the side of the chrystalline, it can only move it obliquely.

Some physiologists have supposed that this black membrane was extended towards the centre of the eye, where the luminous rays are most powerfully concentrated in order to absorb the excess of intense light to which birds are exposed in soaring aloft against the blazing sun. Others have considered it as the gland of the vitreous humour, and that, as this fluid must be rapidly consumed during the frequent and energetic use made of the visual organ by Birds, it therefore might require a superadded vascular structure for its reproduction.

We are inclined to consider the marsupium as an erectile organ, adapted to receive a varying quantity of blood, and to occupy a variable space in the vitreous humour; when fully injected, therefore, it will tend to push forward the lens, either directly or through the medium of the vitreous humour, which must be displaced in a degree corresponding to the increased size of the marsupium; the contrary effects will ensue when the vascular action is diminished. From the analogy of other structures introduced by Supreme Wisdom into the mechanism of organized bodies, it may reasonably be supposed that the marsupium is not limited to a single function.

The *retina* is continued from the circumference of the base of the marsupium, and after forming a few slight folds expands into a smooth layer of medullary matter, which seems to terminate at the periphery of the corpus ciliare. In the Owls, as Haller has observed, not more than half the globe of the eye is lined by the retina; it ceases in fact where the eye loses the spherical form at the base of the anterior cylindrical portion.

The humours of the eye no less correspond to the peculiar vision of the bird, and the rare medium through which it is destined to move, than the shape of the globe and the texture of its coats.

The *aqueous humour* is extremely abundant, owing to the extent of the anterior chamber gained by the convexity of the cornea, and its refractive power must be considerable in the higher regions of the atmosphere. The membrane inclosing it can be more readily demonstrated in birds than in most mammals, especially where it adheres to the free edge of the iris. The large size of the ciliary processes may have the same relation to the reproduction of the aqueous, as the marsupium is supposed to have with reference to the vitreous humour.

The *chrystalline lens* is remarkable for its flattened form, especially in the high-soaring Birds of Prey; it is also of a soft texture, and is without any hard nucleus, as in the eyes of Fishes and Reptiles. In the Cormorant and other birds which seek their food in water, the chrystalline is of a rounder figure, and this is peculiarly the case in the near-sighted Owls which hunt for prey in obscure

* Philosophical Transactions, 1822, p. 76.

† The Parisian Academicians, who took their description of this part from the Ostrich, first applied to it the name of *Marsupium* or *Bourse*. The original description is as follows:—"De cét entonnoir (the termination of the optic nerve) sortoit une membrane plissée, *faisant comme une bourse* qui aboutissoit en pointe vers le bord du Christallin le plus prochain de l'entrée du nerf optique. Cette bourse, qui estoit large de six lignes par le bas, à la sortie du nerf optique, et qui alloit en pointe vers le haut, estoit attachée par sa pointe au bord du Chrystallin, par le moyen de la membrane qui le couvroit du costé de l'humeur vitrée, et qui couvroit aussi toute la bourse qui estoit noir mais d'un autre noir que n'est celuy de la choroïde."—Duvernoy, in 'Mémoires pour servir à l'Hist. Nat. des Animaux,' p. 375.

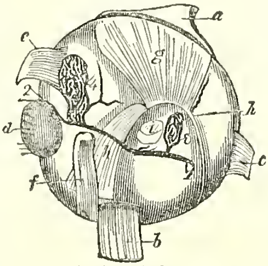
‡ Croonian Lecture, Phil. Trans. 1796.

light. It is inclosed, as in Mammalia, in a distinct capsule, which adheres very firmly to the depression in the anterior part of the vitreous humour; the capsule is itself lodged between two layers of the membrana hyaloidea, which, as they recede from each other to pass—the one in front and the other behind the lens,—leave round its circumference the sacculated canal of Petit.

The vessels of the lens are derived from those of the marsupium, which, as we have before observed, are ramifications of the analogue of the arteria centralis retinæ. With respect to this vessel we may here observe, that it is not continued as a simple branch from its origin to the marsupium,—such a course would be inconsistent with the important functions it is destined to fulfil in the present Class. Immediately before penetrating the coats of the eye it breaks into numerous subdivisions, the aggregate of which is much greater than the trunk whence they proceed, and these again unite, forming a plexus (ε, *fig.* 139) close to the external side of the optic nerve. The artery of the marsupium proceeds from this plexus, and runs along the base of the folds, giving off at right angles a branch to each fold, which in like manner sends off smaller ramuli. The plexus at the origin of the marsupial artery serves as a reservoir for supplying the blood required for the occasional full injection of the marsupium; and a similar but larger plexus (4, *fig.* 139) is formed at the origins of the ciliary arteries which supply the erectile tissue of the ciliary processes and iris. These plexuses are described by Barkow, from whose Memoir* the subjoined figure is taken, but their relation to the erectile powers of the parts they supply appears to have escaped his notice.

The *vitreous humour* presents few peculiarities worthy of note; compared with the aqueous humour, it is proportionally less in quantity than in the eyes of Mammalia. The outer capsule formed by the hyaloid membrane is stronger, and can be more easily separated from the humour.

Fig. 139.



Muscles of the eye.

The Eye-ball is moved in Birds by four straight and two oblique muscles. The *Recti muscles* arise from the circumference of the optic foramen and expand, as they pass forward, to be inserted into the soft middle part of the sclerotic. We have not been able to trace their insertion distinctly to the osseous circle; their aponeurosis cannot be reflected forwards from the sclerotica without lacerating that membrane.

The *Obliqui* both arise very near together from the anterior parietes of the orbit, and go to be inserted, the one into the upper, the other into the lower part of the globe of the eye; the superior obliquus does not pass through a pulley, as in Mammalia.

All the muscles are proportionally short in this class, but especially so in the Owls, in which the eye, from its large size and close adaptation to the orbit, can enjoy but very little motion.

In the subjoined figure and in *fig.* 140, *a′* is the *rectus superior* or *attollens; b′* the *rectus inferior* or *deprimens; c′* the *rectus externus* or *abducens; d′* the *rectus internus* or *adducens; e′* the *obliquus superior; f′* the *obliquus inferior; g′* the *quadratus; h′* the *pyramidalis.*

The accessory parts of the eye in Birds are similar to those of the higher Reptiles. There are three eye-lids, two of which move vertically, and have a horizontal commissure, while the third, which is deeper-seated, sweeps over the eye-ball horizontally, from the inner to the outer side of the globe. The vertical, or upper and lower eye-lids, are composed of the common integument, of a layer of conjunctiva, and between these of a ligamentous aponeurosis, which is continued into the orbit, and lines the whole of that cavity. The lower eye-lid is the one which generally moves in closing the eye in sleep, and it is further strengthened by means of a smooth oval cartilaginous plate, which is situated between the ligamentous and conjunctive layers.

The *orbicularis* muscle is so disposed as by means of this plate to act more powerfully in raising the lower than in depressing the upper eye-lid. In the latter it is continued immediately along the margin: in the lower eye-lid the tarsal cartilage intervenes between the muscle and the ciliary margin.

The *levator palpebræ superioris* arises from the roof of the orbit, and is inserted near the external angle of the lid.

There is also an express muscle for depressing the lower eye-lid, as in the Crocodile.

In the Owls and Night-jar *(Caprimulgus)* the eye-lids are closed principally by the depression of the upper one. There are but few birds that possess eye-lashes; of these the Ostrich is an example, as also the Horn-bills and the Owls, in which they are arranged in a double series; but in these they are rather to be considered as feathers with short barbs, than true eye-lashes.

The third eye-lid, or membrana nictitans, is a thin membrane, transparent in some birds, in others of a pearly white colour, which, when not in action, lies folded back by virtue of its own elasticity on the inner or nasal side of the globe of the eye, with which it is in close contact.

Two muscles are especially provided to effect its movements, but are so placed as to cause no obstruction to the admission of light to the eye during their actions. One of these is called the *Quadratus nictitantis,* (*g, fig.* 139;) it arises from the sclerotica at the upper and back part of the globe of the eye, and its fibres slightly converge as they descend towards the optic nerve, above which they terminate in a

* Meckel's Archiven, B. xii, pl. x.

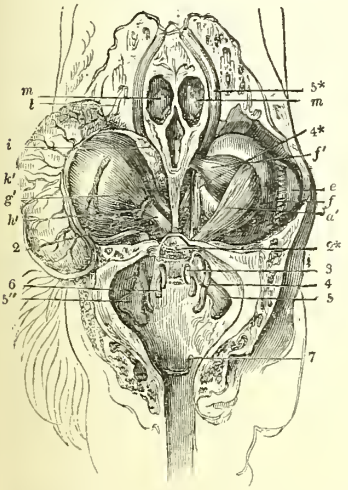
semilunar tendinous sheath, having no express or fixed insertion. The second muscle, called *Pyramidalis nictitantis*, (*h*, *fig.* 139,) arises from the sclerotica from the lower and nasal side of the eye-ball; its fibres converge as they pass to the upper side of the optic nerve, and there terminate in a small round tendon, which glides through the pulley at the free margin of the quadratus, and winding round the optic nerve, passes along a cellular sheath at the lower part of the sclerotica, and is inserted into the lower part of the margin of the third eye-lid, along which it is continued for some distance, and is gradually lost.

By the simultaneous action of the two muscles, the membrana nictitans is drawn forcibly outwards and with an oblique inclination downwards over the anterior part of the eye.* The tendon of the pyramidalis gains the due direction for that action by winding round the optic nerve, and it is restrained from pressing upon that nerve during the action of the pyramidalis muscle by the counteracting force of the *quadratus*, which thus augments the power of the antagonist muscle, while it obviates any inconvenience from pressure on the optic nerve, which its peculiar disposition in relation to that part would otherwise occasion.

To examine this singular and beautiful mechanism, it is necessary to remove the muscles of the eye-ball, especially the *recti*.

Lachrymal Organs.—There are two glands which secrete a fluid to lubricate the ball of the eye, and facilitate the movements of the eye-lids; one of these relates more especially to the movements of the nictitating membrane, and is called from its discoverer the *Harderian Gland;* the other corresponds to the ordinary *Glandula lachrymalis.*

Fig. 140.



* This oblique motion is most remarkable in the Owls, in which the nictitating membrane is accompanied by the upper eye-lid in its sweeping movement across the eye-ball.

The *Glandula Harderiana* (*i*, *fig.* 140) is a conglomeration of mucous follicles, which compensates for the absence of Meibomian glands in Birds; it is generally of large size, situated at the internal angle of the eye, and pours out a thick viscid secretion by a small duct which opens beneath the nictitating membrane. The surface of the gland is divided into many small lobules, which, when injected with mercury, are seen to be composed of still smaller vesicles.

It is interesting to find that some of the Rodentia, which manifest so many affinities to the Class of Birds, have a corresponding gland; in the Hare, for example, it is of large size and bipartite, situated at the internal angle of the orbit, and opening beneath the internal eye-lid.

The true *lachrymal gland* is situated at the external angle of the eye. In the Goose it is of a flattened form, about the size of a pea, opening upon the inside of the outer angle of the eye-lids by a short and wide duct. Its secretion is less viscid than that of the Harderian gland: but this is not uniformly the case.

The lachrymal duct consists of a wide membranous canal commencing by two apertures at the nasal canthus of the eye, and terminating below and a little before the middle or great turbinated cartilage. In the Ostrich there is a glandular prominence at the commencement of each of the lachrymal canals; these seem analogous to the caruncula lachrymalis. In other birds this structure is wanting.

Nasal gland. (*k*, *fig.* 140.)—Besides the lachrymal glands, or those which furnish a fluid for the purpose of lubricating, defending, and facilitating the movements of the eye-ball, there exists another gland, which, from its position within or near the orbit, seems at first sight to appertain to the preceding series, but the secretion of which is exclusively employed in lubricating the pituitary membrane of the nose. This gland, which corresponds to the nasal glands of serpents, and those described by Jacobson* in Mammalia, is situated in many aquatic and marsh birds above the supra-orbital ridge in a depression noticed in the description of the skull, (*p.* 278.) In most birds it is lodged within the orbit itself; in some it is found under the nasal bone, or in the cavity analogous to the maxillary sinus. In the Woodpeckers it is found in the subocular air-cell. It appears to be present in every order of Aves.†

In the Anserine Birds this gland is so situated as to complete the superior margin of the orbit, (*k'*, *fig.* 140,) and is inclosed in an extremely dense fibrous membrane. Its duct (*l*, *fig.* 140) is long, and passes to the nose along an osseous groove, behind the lachrymal bone. Its structure is simple, like that of the salivary glands in the same class, being composed of ramified follicles from which the

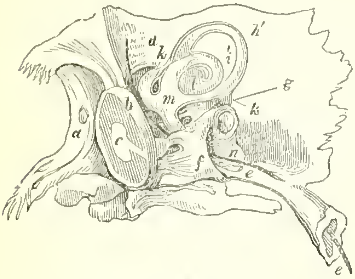
* Nouv. Bullet. des Sc. par la Soc. Philomath. iii. an 6. p. 267.

† *Nitzsch*, Meckel's Archiv. vi. p. 234.

acini of the cells proceed. In the Albatross and Penguin we have traced two or three distinct ducts leading from this gland to the nose.

Organ of Hearing.—The structure of the organs of hearing in Birds resembles most closely that in the higher Reptiles, especially the Crocodile. There is no concha, or projecting

Fig. 141.



Organ of hearing. Owl.

auricle in this class, for collecting and condensing the rays of sound; but to compensate for this deficiency, the labyrinth, and especially the semicircular canals, are of large size in proportion to the cranium. In those Birds, however, which enjoy the locomotive or visual faculties in a less perfect degree than in the rest of the class, there is found a peculiar arrangement of the feathers around the external meatus auditorius, which serves in some degree the office of an external ear. The Ostrich and Bustard (*d, fig.* 155) are so provided, and these birds can raise the auditory circle of plumes to catch distinctly any distant sound that may alarm them. The Owls, again, are furnished with a large crescentic membranous flap, or valve; and the membrana tympani is situated at the bottom of a cavity (*a, fig.* 141), the lining membrane of which is disposed in folds analogous to those of the human auricle. The opercular flap is largely developed in our common Barn-owl (*Strix flammea*). This species is also remarkable in having the membrana tympani attached exclusively to the bony meatus (*b, fig.* 141), and not to the tympanic bone or os quadratum.

The bony framework of the membrana tympani is sunk below the surface of the head, and rarely projects so far from the tympanum as to deserve the name of a meatus or canal: it is deficient anteriorly, where it is bounded by the tympanic bone, to which, with the exception above mentioned, the membrana tympani is attached for a greater or less extent of its anterior circumference.

The drum of the ear (*c, fig.* 141) is more or less of an oval shape; it has the same structure as in Mammals, but is extremely delicate; it is convex externally, as in the Reptiles, not concave, as in most Mammals.

The cavity of the tympanum is widest at its outer part, and very irregular in the rest of its extent. It communicates by the usual foramina with the internal ear, and is connected with the fauces by means of the Eustachian tube. It also communicates by three other apertures with the cells of the bones of the cranium. "These," Macartney observes, "are widened into something like canals, where the holes open into them. The largest of the foramina is in the back of the tympanum, and leads to the posterior cells, and communicates above the foramen magnum with the cellular canal of the other side. The second opening is placed at the anterior part of the tympanum, and conducts to the cells on the lower and anterior part of the cranium. The third foramen is continued amongst the cells which surround the labyrinth. Thus each tympanum has a communication with the interior of all parts of the cranium, and with each other, from which they might be reckoned as making only one cavity. The end of the tympanic bone, also, where it contributes to form the parietes of the tympanum, has a foramen by which it derives its supply of air. The auditory cells of the cranium of birds are analogous to the mastoid of the human subject; but from their extent they multiply sound much more. They are of the greatest magnitude in the nocturnal birds of prey; the Night-jar (*Caprimulgus*) has them also very large: they diminish in size in other birds, in which the posterior canals have no direct communication with each other; they are little observable in the Struthious Birds, and are wanting in the Parrots, but in their place the cavity of the tympanum is enlarged posteriorly."

The *Eustachian tube* (*e, e, fig.* 141) is very large in birds; it is an osseous canal, and terminates by a small aperture close to the one of the other side, within the fissure of the posterior nares. In the Swan the Eustachian passages, after having reached the base of the skull, pass forwards for about half an inch and then unite to form one common tube, which gradually expands until it terminates just behind the posterior apertures of the nose.

The foramina, which lead from the tympanum into the labyrinth, are situated within a fossa. They do not merit the distinctions of *foramen ovale* and *foramen rotundum*, being both oval, and only separated by a small bony process.

The ossicula auditûs are supplied by a single bone, analogous to the stapes, and some cartilaginous processes representing the rudiments of a malleus and incus. The ossiculum consists of a stalk or pedicle, crowned by an oval plate, which is applied to the foramen that leads into the vestibule of the labyrinth. At the other extremity it is united to two or three cartilaginous processes, which form a triangle that is attached to the membrana tympani.

The elongated stapes, or tympanic ossicle, is moved by one muscle (*f, fig.* 141), which comes from the occiput and penetrating the cavity, is affixed to the triangle that is connected to the membrana tympani. This muscle, in consequence of the connections of the ossiculum, is a tensor, and draws the membrana tympani outwards. It is counteracted by two small tendinous cords that are extended to the internal parietes of the tympanum.

The labyrinth of the ear of birds consists of the vestibule, the three semicircular canals, and the rudiment of the cochlea. These parts are included within the bones of the cranium, which form a dense vibratile case *(d)* around the whole internal ear.

The *vestibule* is small in proportion to the other parts, but is more elongated than in the cold-blooded Reptilia.

The *semicircular canals* have been termed by Scarpa, from their gradation in bulk, canales major, minor, and minimus. The largest is most superior, and has a vertical position* *(h, fig.* 141). The smallest is situated horizontally *(k, k)*. The canalis minor or second canal (*i*) is vertical, it ascends upon the horizontal canal, and opens into its side at *m*. They contain corresponding tubes of vascular membrane, and they also possess enlarged ampullæ (*l*), on which the nerves are distributed in the same manner as in mammalia.

The place of the *cochlea* is supplied by a short obtuse osseous conical tube (*n*, *fig.* 141), as in the Crocodile, very slightly bent, with the concavity directed backwards. Its interior is occupied by two small cylinders of fine cartilage, each a little twisted, and united by a thin membrane at their origin and termination. They proceed from the osseous bar, which separates the two foramina, corresponding to the foramen ovale and rotundum. The sulcus, which is left between the cartilages, is dilated near the point, and accommodates the same branch of the auditory nerve, which is sent to the cochlea in mammalia. This nerve spreads in fine filaments upon the united extremity of the cartilaginous cylinders. The tube is divided by the presence of the cartilages into two scalæ, the anterior of which communicates with the vestibule and is not closed; the posterior scala is shorter, and communicates with the tympanum by the foramen rotundum, which is closed by a membrane. Besides these parts the cochlea still contains a trace of the cretaceous substance which forms so conspicuous a part of the organization of the internal ear in Fishes.

The Struthious birds manifest their close relation to the Reptilia by having the tube corresponding to the cochlea, very small in proportion to the other parts.

The seventh cerebral nerve is received into a fossa, and there divides into five branches; one is the facial, or portio dura, and the others are sent to the semicircular canals and the tube. The facial nerve receives a filament from the par vagum, which traverses the ear, and is afterwards distributed to the palate.

Comparetti has described two canals leading from the labyrinth of birds, which correspond with the aqueducts of the mammalia.*

Organ of Smell.—The close affinity subsisting between the cold and warm-blooded ovipara is no where more strongly manifested than in the olfactory organs. The external nostrils are simple perforations, having no moveable cartilages or muscles provided for dilating or contracting their apertures, as in mammalia. The extent of surface of the pituitary membrane is not increased by any large accessory cavities, but simply by the projections and folds of the turbinated bones. The olfactory nerve is simple, as in the Tortoise, and passes out of the skull, as before observed, by a single foramen.

The external nostrils vary remarkably both in shape and position, and serve on that account as zoological characters. They are placed at the sides of the upper mandible in the majority of birds, but in some species are situated at or above the base of the bill; the latter is the case in the Toucans; in the *Apteryx Australis* they are found at the extremity of the long upper mandible.

In general they are wide and freely open to facilitate the inhalation of air during the rapid motions of the bird, but sometimes they are so narrow that, as in the Herons, they will scarcely admit the point of a pin; and in the Gannet they have been supposed, but erroneously, to be wanting altogether.†

In the *Rasores* the nostrils are partially defended by a scale. In the *Corvidæ* they are protected by a bunch of stiff feathers directed forwards. In the Petrels the nostrils are produced in a tubular form, parallel to one another for a short distance along the upper part of the mandible, with the orifices turned forwards *(a, fig.* 142.)

The septum narium is, in general, complete, and is partly osseous, partly cartilaginous. It is perforated in the Swan just opposite the external nostrils. The surface of the septum is very irregular in this bird, and the pituitary membrane which covers it is highly vascular.

The outer side of each of the nasal passages gives attachment to three turbinated laminæ. The inferior one is a simple fold adhering to the septum narium as well as to the side of the nose; the middle one is cartilaginous and is the largest. It is of an infundibular figure, and adheres by its base to the septum of the nose, and externally to the cartilaginous *ala* or side of the nostril. It is convoluted with two turns and a half in the Anserine Birds, but in the *Grallatores* it is compressed and forms only one turn and a half. The superior turbinated lamina *(m m, fig.* 140) generally presents the form of a bell; it is also cartilaginous, and adheres to the ethmoidal and lachrymal bones. It is hollow, and divided into two compartments, which are prolonged in a tubular form; the internal one extends to

* In the Insessores this canal is generally the smallest of the three.

* See Cuvier, Leçons d'Anat. Comp. tom. ii., and Macartney in Rees' Cyclopædia, Art. *Birds*.

† See Montague's Ornithological Dictionary.

the orbit, the external terminates behind the middle turbinated lamina in a cul-de-sac. These olfactory laminæ differ in regard to texture. In the Cassowary and Albatross they are said to be membranous. Cuvier states that they appeared to him to be bony in the Hornbill and Toucan. We have found this to be the case in the recent Toucan. The organ of smell in this singular species is confined to the base of its enormous beak, (*d, e, fig.* 150.) The canal, which is traversed by the air and odorous particles in inspiration, forms a sigmoid curve in the vertical direction. The external orifice is on precisely the same perpendicular line as the internal, or, as it is generally termed, the posterior nasal aperture. The external nostril (*d, fig.* 150) being situated on the posterior surface of the upper mandible, where it is raised above the level of the cranium, is consequently directed backwards, secure from all injury to which it might be exposed while the bill was used in penetrating dense and interwoven foliage. The olfactory canal is at its commencement of a cylindrical form, and about two lines in diameter. It passes forwards for about half an inch, receiving the projection of the first spongy bone, then bends downwards and backwards, and is dilated to admit the projections of the two other spongy bones. From this point it descends vertically to the palate, at first contracted and afterwards dilating to form the internal or posterior orifice, (*e, fig.* 150.) The first or outermost spongy bone is almost horizontal, and has its convexity directed outwards. The second is nearly vertically placed, with its convexity directed backwards: it terminates in a narrow point below. The superior spongy bone is about the size and shape of a pea. All these bones are processes from the inner and posterior parietes of the nasal passage; they are cellular, and air is continued into them from the cranial diploë; but the parietes of the nasal passage are entire and smooth, and lined by a delicate pituitary membrane, so that there is no direct communication between the cells, the turbinated bones, or of the mandible and the nasal passages.

In most birds the nasal cavities communicate with the pharynx by two distinct but closely approximated apertures. In the Cormorant, however, these join into one before their termination posteriorly, which is consequently by a single aperture. The olfactory nerves are distributed exclusively to the pituitary membrane covering the septum narium and the superior spongy bone. The pituitary membrane is of the most delicate structure, and is most vascular, where it covers the superior turbinated lamina, and becomes thicker and more villous as it descends upon the middle one. It everywhere displays numerous pores of muciparous glands, which bedew it with a lubricating secretion.

According to Scarpa the acuteness of smell is exactly in proportion to the development of the superior turbinated lamina, to which the size of the olfactory nerve corresponds. The following is the order in which, according to his experiments, birds enjoy the sense of smell, beginning with those in which it is most acute: *Grallatores, Natatores, Raptores, Scansores, Insessores, Rasores.*

There is still, however, much obscurity with reference to the extent to which Birds make use of their olfactory organs. It has been generally asserted that birds of prey are gifted with a highly acute sense of smell, and that they can discover by means of it the carcass of a dead animal at great distances; but those who have witnessed the rapidity with which the Vultures descend from invisible heights of the atmosphere to the carcass of an animal, too recently killed to attract them by putrefactive exhalations, have generally been led to consider them as being directed to their quarry by sight. "That this is the case," Dr. Roget observes, "appears to be now sufficiently established by the observations and experiments of Mr. Audubon, which show that these birds in reality possess the sense of smell in a degree very inferior to carnivorous quadrupeds, and that so far from guiding them to their prey from any distance, it affords them no indication of its presence even when close at hand. The following experiments appear to be perfectly conclusive on this subject. Having procured the skin of a deer, Mr. Audubon stuffed it full of hay; after the whole had become perfectly dry and hard, he placed it in the middle of an open field, laying it down on its back in the attitude of a dead animal. In the course of a few minutes afterwards he observed a vulture flying towards and alighting near it. Quite unsuspicious of the deception, the bird immediately proceeded to attack it as usual in the most vulnerable points. Failing in this object, he next with much exertion tore open the seams of the skin where it had been stitched together, and appeared earnestly intent on getting at the flesh, which he expected to find within, and of the absence of which not one of his senses was able to inform him. Finding that his efforts, which were long reitcrated, led to no other result than the pulling out large quantities of hay, he at length, though with evident reluctance, gave up the attempt, and took flight in pursuit of other game to which he was led by the sight alone, and which he was not long in discovering and securing.

"Another experiment, the converse of the first, was next tried. A large dead hog was concealed in a narrow and winding ravine, about twenty feet deeper than the surface of the earth around it, and filled with briers and high cane. This was done in the month of July, in a tropical climate, where putrefaction takes place with great rapidity; yet, although many vultures were seen from time to time sailing in all directions over the spot where the putrid carcass was lying, covered only with twigs of cane, none ever discovered it; but in the meanwhile several dogs had found their way to it and had devoured large quantities of the flesh."*

* See Roget, Bridgewater Treatise, vol. ii. p. 406.

Organ of Taste.—The gustatory sense is very imperfectly enjoyed in birds, which, having no manducatory organs, swallow the food almost as soon as seized. The tongue is organized chiefly to serve as a prehensile instrument, and its principal modifications will be treated of under the head of the *Digestive Organs.* It is generally sheathed at the anterior part with horn (*h*, *fig.* 152), and is destitute of papillæ except at its base (*o*, *fig.* 152) near the aperture of the larynx; these papillæ are not, however, supplied by a true gustatory nerve, but by filaments of the glossopharyngeal. No branch of the fifth pair goes to the tongue.

The tongue is proportionally largest and most fleshy in the Parrot tribe, and the food is detained in the mouth longer in these than in other birds. It is triturated and comminuted by the mandibles certainly, and turned about by the tongue, which here seems to exercise a gustatory faculty, since indigestible parts, as the coat of kernels, &c. are rejected. In the Lories the extremity of the tongue is provided with numerous long and delicate papillæ or filaments projecting forwards.

Organs of Touch.—With respect to the tactile instruments, but few observations can be made in the class of Birds. The anterior extremities have their digital extremities undivided and entirely unfitted for the exercise of this sense, and the posterior extremities are but little better organized for the purpose. The integument covering the toes is very sparingly supplied with nerves, and is of a texture scarcely fitted for ascertaining the superficial qualities of bodies. However, the villi on the under surface of the toes are observed to be remarkably long in the Capercailzie (*Tetrao urogallus*), but this is probably for the purpose of enabling them to grasp with more security the frosted branches of the Norwegian pine-trees. The Parrots seem to use their feet more like instruments of touch, but in them the action may be merely prehensile.

The only organ of touch respecting which there can be no doubt is the bill. Even where this is covered with a hard sheath of horn, some filaments of the fifth pair (*c*, *fig.* 150) may be traced terminating in small papillæ; but in the Lamelli-rostral water-birds the bill is covered by a softer substance, and is plentifully supplied by branches of the fifth pair of nerves. (See *Nerves.*) In the Woodcocks and Snipes the long bill is so organized that it is used as a probe in marshes and soft ground to feel for the small worms and slugs that constitute their food.

The cire in the *Falconidæ*, the *wattles* of the Wattle-birds (*Philedon carunculatus* and *Glaucopis cinerea*) and of the Cock, the caruncles of the King-Vulture and Turkey, may also be regarded in some degree as organs of touch.

Organs of Digestion.—The digestive function in birds is necessarily extremely powerful and rapid in order to supply the waste occasioned by their extensive, frequent, and energetic motions, and in accordance with the rapidity of their circulation and their high state of irritability.*

The parts to be considered with reference to this function are the rostrum or beak, the tongue, the œsophagus, the stomach which is always divided into a glandular and muscular portion, the intestines, and the cloaca.

The glandular organs of the digestive system are the salivary glands, the proventricular follicles, the liver, pancreas, and spleen.

The *beak* consists of the maxillary and intermaxillary bones, which in place of teeth are provided with a sheath of horny fibrous material, exactly similar to that of which the claws are composed: this sheath is moulded to the shape of the osseous mandibles, being formed by a soft vascular substance covering these parts, and its margins are frequently provided with horny processes or laminæ secreted by distinct pulps, and analogous in this respect to the whalebone laminæ of the Whale: M. Geoffroy St. Hilaire has described a structure in the bill of birds which presents a closer approach to a dentary system. In a fœtus of a Perroquet nearly ready for hatching, he found that the margins of the bill were beset with tubercles arranged in a regular order and having all the exterior appearances of teeth: these tubercles were not, indeed, implanted in the jaw-bones, but formed part and parcel of the exterior sheath of the bill. Under each tubercle, however, there was a gelatinous pulp, analogous to the pulps which secrete teeth, but resting on the edge of the maxillary bones, and every pulp was supplied by vessels and nerves traversing a canal in the substance of the bone. These tubercles form the first margins of the mandibles, and their remains are indicated by canals in the horny sheath subsequently formed, which contain a softer material, and which commence from small foramina in the margin of the bone.

The different degrees of hardness and varieties of form of the beak exercise, Cuvier observes,† as much influence upon the nature of birds as the number and figure of the teeth do upon that of Mammals.

The beak is hardest in those birds which tear their prey, as in Eagles and Falcons; or in those which bruise hard seeds and fruits, as Parrots and Gros-beaks; or in those which pierce the bark of trees, as Woodpeckers, in the larger species of which the beak absolutely acquires the density of ivory.

The hardness of the covering of the beak gradually diminishes in those birds which take less solid nourishment, or which swallow their food entire; and it changes at last to a soft skin in those which feed on tender substances, or which have occasion to probe for their food in muddy or sandy soils, or at the bottom of the water, as Ducks, Snipes, Woodcocks, &c.

Cæteris paribus, a short beak must be stronger than a long one, a thick one than a thin one, a solid one than one which is flexible; but the

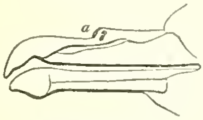
* The Cormorant readily devours six or eight pounds of fish daily.

† Anatomie Comparée, tom. ii. p. 192.

general form produces infinite variety in the application of the force.

A compressed beak with sharp edges and a hooked extremity characterizes both the Birds of Prey properly so called, which destroy the smaller quadrupeds and birds (*fig.* 112); and also the carnivorous species of a different order that live on fish, as the Petrels (*fig.* 142), Al-

Fig. 142.



Bill of the Petrel.

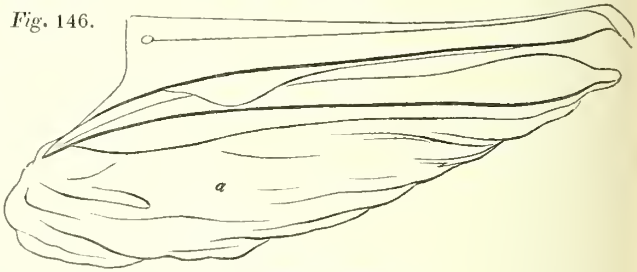
batrosses, Frigate-bird, and Tropic-bird. But in the *Raptores* it is comparatively shorter and stronger, and in some genera a tooth-like process on either side adds considerably to its destructive powers: hence the Falcons which possess this armature are reckoned the more 'noble' and courageous Birds of Prey.

The Insessorial Shrikes which have their bill similarly armed do not yield in courage to the Hawks, notwithstanding their small size, and the comparative feebleness of their wings and feet: (*fig.* 115.)

As the bill becomes narrower and straighter, it characterizes birds of a voracious habit, but less daring in their attacks on other birds, such as the Crows, Magpies, &c., (*fig.* 116); and the compressed knife-shaped bill is associated with similar habits in the Water-birds, as the Gulls, Grebes, Dabchicks, &c.

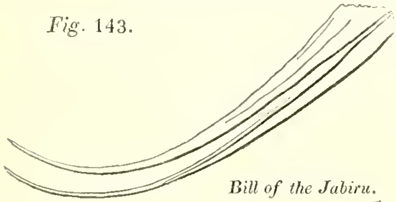
Another kind of strong and trenchant bill, which is more elongated and without a hook, serves to cut and break, but not to tear: this form of bill characterizes the Waders which frequent the water and prey upon animals that make resistance in that element, as reptiles, fishes, &c. In the Herons and Bitterns the bill is straight; in the Ibis it is curved downwards (*fig.* 123); in the Jabiru (*fig.* 143) it is curved in the contrary direction.

Fig. 146.



Bill of the Pelecan.

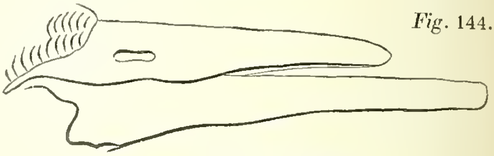
Fig. 143.



Bill of the Jabiru.

Some trenchant or sharp-edged bills are so compressed as to resemble the blade of a knife, and can only serve to seize small objects, which are immediately swallowed: such is the form of the beak in the Auks, Puffins, Coulterneb, (where it has the further peculiarity of being as deep as it is long), and the Skimmer (*Rhyncops*), in which the still more singular structure obtains of an inequality in the length of the two mandibles, the upper one being considerably the shortest; so that this bird can only get its food, which consists of floating marine animals, by pushing them before it as it skims along the surface of the water.

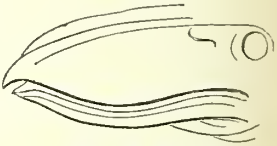
Fig. 144.



Bill of the Skimmer.

Lastly, there are trenchant bills which are depressed or flattened horizontally; they serve to seize fishes and reptiles, and other large objects; the Boat-bill (*Cancroma*) exhibits a bill of this kind (*fig.* 145), which is also serrated at the edges. Some species of Fly-catcher and Tody have this form of beak on a small scale.

Fig. 145.

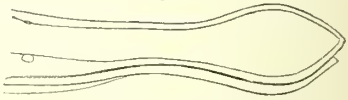


Bill of the Boat-bill.

Of the blunt-edged bills we may first notice those which are flattened horizontally. When a bill of this description is long and strong, as in the Pelecan (*fig.* 146), it serves to seize a large but feebly resisting prey, as fishes.

When it is long and weak, as in the Spoonbill, which derives its name from the dilated extremity of the mandibles, it is only available to seize amid sand, mud, or water, very small Crustaceans, Mollusks, &c. (*fig.* 147.)

Fig. 147.



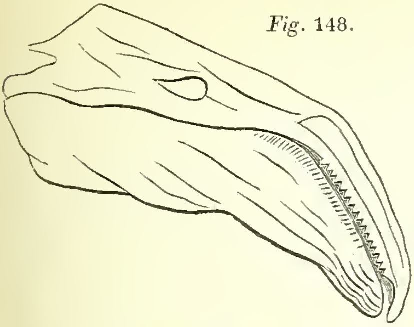
Bill of the Spoonbill.

The more or less flattened bills of Ducks, the more conical ones of Geese and Swans, and that of the Flamingo,* of which the extremities

* It is singular that it should ever have been supposed that the upper mandible was alone moveable, and the lower mandible perfectly immoveable, in the Flamingo, since precisely the contrary is the

of the mandibles are bent downwards abruptly (*fig.* 148), have all transverse horny laminæ

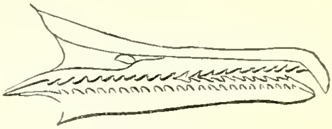
Fig. 148.



Bill of the Flamingo.

arranged along their edges, which, when the bird has seized any object in the water, serve, like the whalebone laminæ of the Whale, to give passage to the superfluous fluid. The aquatic habits of all these birds are in harmony with this structure. In the Goosanders (*Mergus*), which are nearly allied to the *Anatidæ*, the lateral laminæ are developed into small conical tooth-like processes, which serve to hold fast the fishes, which the Goosander destroys in great numbers.

Fig. 149.

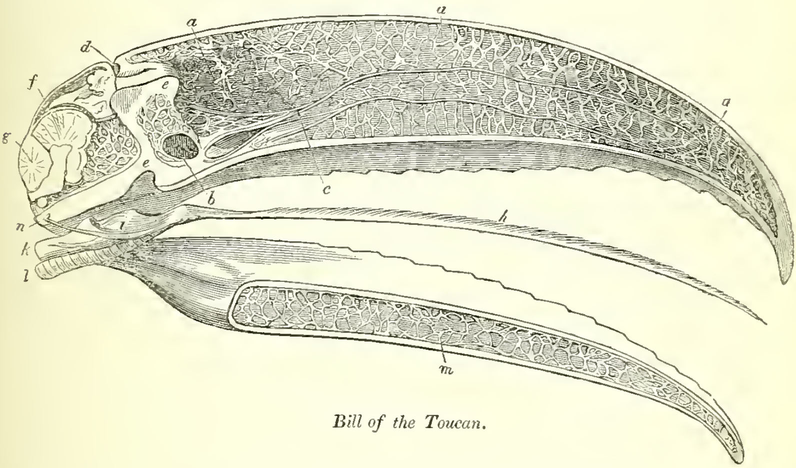


Bill of the Goosander.

The bills of the Toucans and Hornbills are remarkable for their enormous size, which is sometimes equal to that of the whole bird. The substance of the beak in these cases is extremely light and delicately cellular, without which the equilibrium necessary for flight would have been destroyed. The singularity of the structure of these bills demands a more particular consideration.

The osseous portions of the mandibles of the Toucan (*fig.* 150) are adapted to com-

Fig. 150.



Bill of the Toucan.

bine, with great bulk, a due degree of strength and remarkable lightness, and their structure is consequently of a most beautiful and delicate kind. The external parietes are extremely thin, especially in the upper beak: they are elastic, and yield in a slight degree to moderate pressure, but present considerable resistance if the force be increased for the purpose of crushing the beak. At the points of the mandibles the outer walls are nearly a line in thickness; at other parts in the upper beak they are much thinner, varying from one-thirtieth to one-fiftieth part of an inch, and in the lower beak are from one-twentieth to one-thirtieth of an inch in thickness.

On making a longitudinal section of the upper mandible (*a*, *fig.*150) in the *Rhamphastos Touco*, its base is seen to include a conical cavity about two inches in length and one inch in diameter, with the apex directed forwards. The walls of this cone consist of a most beautiful osseous net-work, intercepting irregular angular spaces, varying in diameter from half a line to two lines. From the parietes of the cone a net-work of bony fibres is continued to the outer parietes of the mandible, the fibres which immediately support the latter being almost invariably at right angles to the part in which they are inserted. The whole of the mandible anterior to the cone is occupied with a similar net-work, the meshes of which are largest in the centre of

case. In the specimen which we dissected (see Proceedings of the Zoological Society, Part ii. p. 141) the upper mandible was so firmly fixed to the cranium as only to be moved with that part, while the lower mandible was freely moveable when the head was fixed. The Flamingo is remarkable for applying the upper mandible to the soil, which it shovels backwards in searching for its food.

the beak, in consequence of the union which takes place between different small fibres as they pass from the circumference inwards. It is worthy of observation that the principle of the cylinder is introduced into this elaborate structure: the smallest of the supporting pillars of the mandibles are seen to be hollow or tubular when examined with the microscope. The structure is the same in the lower mandible (*m*, *fig*. 150), but the fibres composing the net-work are in general stronger than those of the upper mandible.

The medullary membrane lining these cavities appears to have but a small degree of vascularity. Processes of the membrane, accompanying vessels and nerves, decussate the conical cavity at the base of the beak. The air is admitted to the interior of the upper mandible from a cavity (*b*, *fig*. 150) situated anterior to the orbit, which communicates at its posterior part with the air-cell continued into the orbit, and at its anterior part with the maxillary cavity. The nasal cavity is closed at every part except at its external and internal apertures by the pituitary membrane, and has no communication with the interior of the mandible.*

The horny sheath of the mandibles in the Hornbills and Toucans is so thin that it often becomes irregularly notched at the edge from use. The Hornbills have, besides, upon their enormous beak, horn-like prominences of the same structure and of different forms, the use of which is not known.

The Trogons, Touracos, Buccos, &c. exhibit forms of the bill which are intermediate to that of the large but feeble bill of the Toucans, and the short, but hard, strong, and broad bill of the Parrot-tribe, which is also hooked, so as to assist in climbing, like a third foot: (*fig*. 128.)

The short, conical, and vaulted beak of the *Rasores* (*fig*. 121) serves to pick up with due rapidity the vegetable seeds and grains which constitute their food, as well as small insects, as ants, &c. with which the young are frequently nourished.

The bills of the small Insessorial or Passerine birds present every gradation of the conical form, from the broad-based cone of the Hawfinch to the almost filamentous cone of the Humming-birds (*fig*. 117, 125), and each of these forms influences the habits of the species in the same manner as in the larger birds. The short and strong-billed Insessores live on seeds and grains; those with a long and slender bill on insects or vegetable juices. If the slender bill be short, flat, and the gape very wide, as in Swallows, the bird takes the insects while on the wing (*fig*. 118); if the bill be elongated and endowed with sufficient strength, as in the Hoopoes, it serves to penetrate the soil and pick out worms, &c.

Of all bills, the most extraordinary is that of the Cross-bill, in which the extremities of the mandibles curve towards opposite sides and cross each other at a considerable angle—a disposition which at first sight seems directly opposed to the natural intention of a bill. With this singular disposition, the Cross-bill, however, possesses the power of bringing the points of the mandibles into contact with each other; and Mr. Yarrell, in his excellent paper on the Anatomy of the Beak of this bird, observes that, notwithstanding M. Buffon's assertion to the contrary, it can pick up the smallest seeds, and shell or husk hemp and similar seeds like other birds. He further shows that the disposition and power of the muscles is such that the bill gains by its very apparent defect the requisite power for breaking up the pine-cones that constitute its natural food. In a pair of Cross-bills which were kept for some time in captivity, one of their principal occupations, Mr. Yarrell observes, "was twisting out the ends of the wires of their prison, which they accomplished with equal ease and dexterity. A short flat-headed nail that confined some strong net-work was a favourite object upon which they tried their strength, and the male, who was usually pioneer in every new exploit, succeeded, by long-continued efforts, in drawing this nail out of the wood, though not without breaking off the point of his beak in the experiment. Their unceasing destruction of cages at length brought upon them sentence of banishment." He concludes his memoir by observing that "the remarks of Buffon on the beak of this bird, which he characterizes as 'an error and defect of nature, and a useless deformity,' exhibit, to say the least of them, an erroneous and hasty conclusion, unworthy of the spirit of the science he cultivated. During a series of observations on the habits and structure of British Birds, I have never met with a more interesting or beautiful example of the adaptation of means to an end than is to be found in the tongue, the beak, and its muscles, in the Cross-bill."*

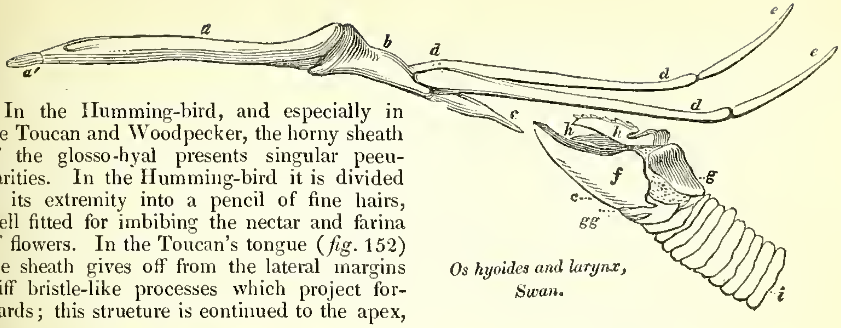
The *tongue*, as has been already observed, can hardly be considered as an organ of taste in Birds, since, like the mandibles, it is generally sheathed with horn. It is principally adapted to fulfil the offices of a prehensile organ in association with the beak, and it presents almost as many varieties of form. Ornithologists have not yet perhaps derived all the advantages which a study of the modifications of the tongue might afford in determining the natural affinities of birds.

The os hyoides very much resembles that of Reptiles. Its parts have been minutely studied by Geoffroy St. Hilaire, who has bestowed upon them separate names: (*a*, *fig*. 151) is the glosso-hyal, *b* the basi-hyal, *d d* the apo-hyals, *e e* the cerato-hyals, *c* the uro-hyal. The body, or basi-hyal element, is more thickened than the rest: in some birds it is cylindrical. The length of the tongue depends chiefly on that of the lingual process or glosso-hyal element. In most birds it is lengthened out by a cartilage *a'* appended to its extremity. This is remarkable in the Swan and other *Lamelli-rostres*.

* See Anatomical Appendix to Gould's Monograph on the *Ramphastidæ*, fol.

* Zool. Journal, vol. iv. p. 464.

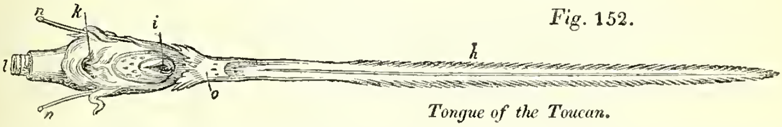
Fig. 151.



Os hyoides and larynx, Swan.

In the Humming-bird, and especially in the Toucan and Woodpecker, the horny sheath of the glosso-hyal presents singular peculiarities. In the Humming-bird it is divided at its extremity into a pencil of fine hairs, well fitted for imbibing the nectar and farina of flowers. In the Toucan's tongue (*fig.* 152) the sheath gives off from the lateral margins stiff bristle-like processes which project forwards; this structure is continued to the apex,

Fig. 152.

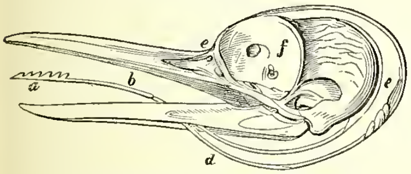


Tongue of the Toucan.

and the tongue so provided becomes an instrument for testing the softness and ripeness of fruit, and the fitness of other objects for food, thereby acting as a kind of antenna or feeler. A similar but less developed structure is found in the tongue of the frugivorous Touraco.

In the Woodpeckers the apex of the horny sheath (*a, fig.* 153, 154) gives off at the sides short-pointed processes directed backwards, which thus convert it into a barbed instrument, fitted for holding fast the insects which its sharp point has transfixed, after the strong beak has dislodged them from their hiding places. The cornua of the os hyoides in the Woodpecker extend backwards to the vertebral column, wind round the back of the head, and converge as they pass forwards to be inserted in a canal generally on the right side of the upper mandible (*d, e, fig.* 153, 154.)

Fig. 153.



Cranium and tongue of a Woodpecker.

One of the most remarkable structures which the tongue presents in this class is met with in the Flamingo, where it is remarkable both for its size, texture, and singular armature. The tongue is almost cylindrical, slightly flattened above, and obliquely truncate anteriorly, so as to correspond with the form of the inferior mandible. The pointed extremity of the truncated part is supported beneath by a small horny plate. Along the middle of the upper surface there is a moderately deep and wide longitudinal furrow; on either side of which there are from twenty to twenty-five recurved spines, from one to three lines in length. These spines are arranged in an irregular alternate series: the outer ones being the smallest, which may almost be considered as a distinct row. At the posterior part of the tongue there are two groups of smaller recumbent spines directed towards the glottis. The substance of the tongue is not muscular, but is chiefly composed of an abundant elastic cellular substance, permeated by an oily fat.

In the *Raptores* the tongue is of a moderate length,—broad, and somewhat thick, and has a slight division at the tip. In the Vultures its sides can be voluntarily approximated so as to form a canal, and its margins are provided with retroverted spines. In the Raven it is bifid at the apex.

In the Struthious birds, in many of the Waders, and in the *Pelecanidæ*, the tongue is remarkably short.

In the Parrots it is thick and fleshy, serves admirably to keep steady the nut or seed upon which the strength of the mandibles is exerted, and is applied to the kernel so extracted, as if to ascertain its sapid qualities.

The following are the muscles of the tongue in birds.

1st. The *Genio-hyoideus* of Vicq d'Azyr, or the *Mylo-hyoideus* according to Cuvier. This is a thin layer of fibres attached to the lower and inner border of the lower jaw, and running transversely to a mesial tendon which separates them, and extends to the uro-hyal. It raises the tongue towards the palate.

2d. The *Stylo-hyoideus* arises from the upper and back part of the lower jaw, and divides into three or more portions: the *posterior* descends obliquely forwards, and is inserted into the tendinous commissure of the preceding muscle; the *middle* portion is inserted into the 'uro-hyal:' the *anterior* fasciculus is inserted into the side of the basi-hyal above the transverse hyo-glossus. The actions of these different portions vary according to their insertion; the first and second depress the apex of the tongue by raising its posterior appendage, (uro-hyal,) the third raises the tongue and os hyoides, and draws it to one side when it acts singly.

3d. The *Genio-hyoideus* arises by two fleshy bands from the lower and internal edge of the lower jaw; these unite and surround the cerato-hyals or cornua of the os hyoides; and as they draw forward the os hyoides, protrude the tongue from the beak.

4th. The *Cerato-hyoideus* passes from the cerato-hyal to the uro-hyal, and is therefore subservient to the lateral movements of the tongue.

5th. The *Sterno-hyoidei* are replaced by a slip of muscle which extends from the anterior surface of the upper larynx to be attached to the base of the glosso-hyal.

6th. A small and short muscle is single or azygos; it passes from the basi-hyal to the under part of the glosso-hyal; it depresses the tip of the tongue and elevates its base.

7th. A short muscle which arises from the junction of the basi-hyal with the cerato- and uro-hyals, and is inserted into the upper and outer angle of the base of the glosso-hyal.

All these muscles are remarkably large in the Woodpecker, in which there is a singular pair of muscles that may be termed *Cerato-tracheales*, (*h*, *fig.* 154.) They arise from the trachea about eight lines from the upper larynx, twist four times spirally round the trachea, and then pass forward to be inserted into the base of the cerato-hyals. This is the principal retractor of the singular tongue in this species.

Salivary glands.—The salivary organs, being in general developed in a degree corresponding to the extent of the changes which the food undergoes in the mouth, and the length of time during which it is there detained, are by no means so conspicuous a part of the digestive system in Birds as in Mammals. Glands which pour out their secretion upon the food prior to deglutition are, however, met with in every bird, but vary in number, position, and complexity of structure.

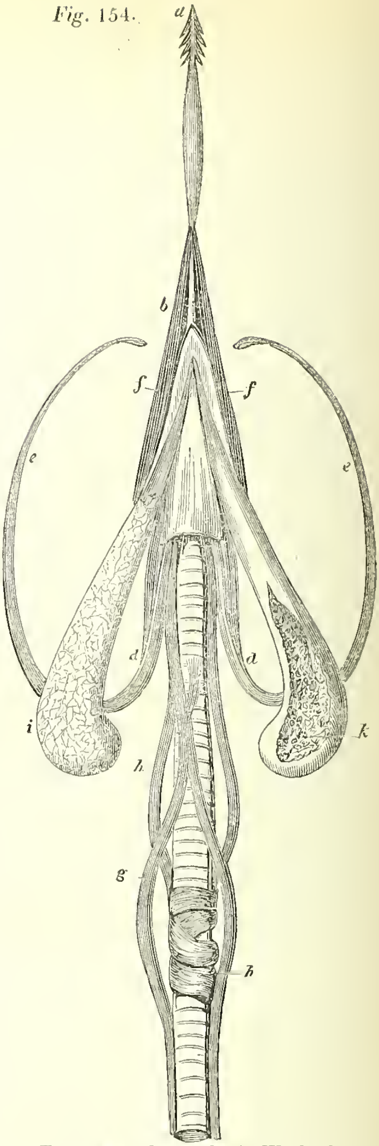
In some species, as the Crow, they are of the simplest structure, consisting of a series of unbranched, cone-shaped follicles or tubules, opening separately upon the mucous membrane of the mouth, along the sides of which cavity they are situated. They pour out a viscid mucus, and are the only traces of a salivary system met with in this bird.

In many other birds, and especially in the Scratching, Wading, and Swimming Orders, glands of the conglomerate structure are found beneath the lower jaw, analogous to the submaxillary glands of quadrupeds.

In the Goose they occupy the whole of the anterior part of the space included by the rami of the lower jaw, being of an elongated form, flattened and closely united together at the middle line. On either side of this line the mucous membrane of the mouth presents internally a series of pores, each of which is the terminal orifice of a distinct gland or aggregate of ramified ducts.

A third and higher form of salivary gland, in which the secretion of the conglomerate mass is conveyed into the mouth by a single duct, is found in the Woodpeckers and some species of the Rapacious Order. In the latter birds these glands are termed, from their situation, *anterior palatine*: in the *Picæ* they correspond to the parotid and sublingual of Quadrupeds.

Fig. 154.



Tongue and salivary glands, Woodpecker.

The sublingual glands of the Woodpecker are of extraordinary size, extending from the angle to the symphysis of the lower jaw. The single ducts of each gland unite just before their termination, which is a simple orifice at the apex of the mouth. The structure of these glands is shown at *i*, *k*, *fig.* 154.

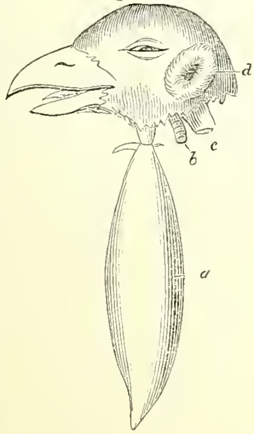
Besides the preceding, which may be considered as the true salivary glands, there are numerous accessory follicles in different parts of the oral apparatus of birds. In the Water-hen (*Gallinula chloropus*) there is a series of cœcal glandular tubes along each side of the tongue; and it is interesting to note that glandular follicles are found abundantly developed on the tongues of the Chelonian and Saurian reptiles. Similar elongated follicles are situated along the margin of the lower jaw, resembling in their parallel pectinated disposition the branchiæ of Fishes. In the Goose the corresponding follicles are longer and wider, and are situated near the sides of the tongue. In the Raven these mucous follicles are narrower but longer.

The food, after being embued with the secretion of the preceding glands, is poised upon the tongue and swallowed partly by means of the pressure of the tongue against the palate, partly by a sudden upward jerk of the head. The posterior apertures of the nostrils being generally in the form of narrow fissures are undefended by a soft palate or uvula; and the laryngeal aperture, which is of a similar form, is in like manner unprovided with an epiglottis, but is defended by the retroverted papillæ at the base of the tongue. In many birds, indeed, as the Albatross and Coot, there is a small cartilage in the usual place of an epiglottis, but insufficient to cover more than a very small part of the laryngeal aperture. Nitzsch has devoted a treatise to these rudimentary epiglottides in Birds.*

With respect to the fauces the remarkable instance of a dilatation of these parts in the Pelecan must not be forgotten. The extensibility of the membrane between the rami of the lower jaw admits of its formation into a bag (*a*, *fig.* 146), which is calculated to contain ten quarts of water, and serves as a receptacle for fishes, making in that state a conspicuous appendage to the huge bill; when empty it can be contracted so as to be hardly visible. By means of this mechanism a quantity of food can be transported to the young; and, as in disgorging the bleeding fishes the parent presses the bottom of the sac against her breast, this action has probably given rise to the fable of her wounding herself to nourish the young with her own blood.

A remarkable provision of an analogous nature is met with in the Bustard as a sexual peculiarity (*fig.* 155). In the male there is a membranous sac extending for some way down the anterior part of the neck capable of holding several quarts of water; it communicates with the mouth by an aperture beneath the tongue. It is not found except in the mature bird. It is supposed to serve the purpose of providing the female and young during the breeding season with water, and hence may not be developed to its full extent except at that period.

Fig. 155.



Faucial bag of the Bustard.

* See Meckel's Archiven, 1826, p. 613.

The Swift presents an analogous dilatation of the membrane of the fauces at the base of the lower jaw and upper part of the throat: it is most developed at the period of rearing the young, when it is generally found distended with insects in the old birds that are shot while on the wing. This receptacle is of a rounded form, and communicates with the fauces by a wider opening than that of the Bustard; it is also proportionally of less extent. A similar structure obtains in the Rook and probably in other Insectivorous birds.

The œsophagus (*H*, *fig.* 171: *a*, *fig.* 156, 158), like the neck, is usually very long in birds: as it passes down, it generally inclines towards the right side; it is partially covered by the trachea (*G*, *fig.* 171), and connected to the surrounding parts by a loose cellular tissue. It is wide and dilatable, corresponding to the imperfection of the oral instruments as comminutors of the food. In the rapacious and especially in the piscivorous birds it is of great capacity, enabling the latter to swallow the fishes entire, and serving also in many Waders and Swimmers as a temporary repository of food.

When the Cormorant has by accident swallowed a large fish, which sticks in the gullet, it has the power of inflating that part to its utmost, and while in that state the head and neck are shaken violently, in order to promote its passage. In the Gannet the œsophagus is extremely capacious, and, as the skin which covers it is equally dilatable, five or six herrings may be contained therein. In both these species it forms one continued canal with the stomach.

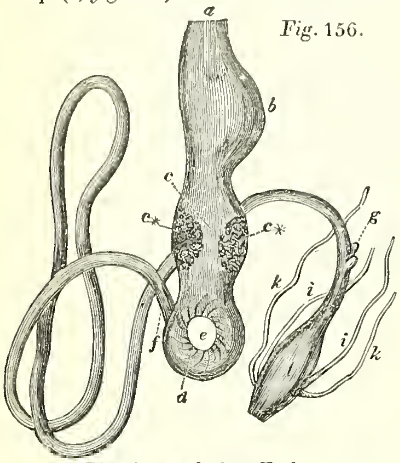
In the Flamingo, on the contrary, the diameter of the gullet does not exceed half an inch, being suited to the smallness of the objects which constitute the food of this species.

Besides deglutition the œsophagus is frequently concerned in regurgitation; and in the Birds in which this phenomenon occurs, the muscular coat of the gullet is well developed, as in the Ruminant Mammalia. The *Raptores*, for example, habitually regurgitate the bones, feathers, and other indigestible parts of their prey, which, in the language of the falconer, are called 'castings.' A Toucan, which was preserved some years alive in this country, was frequently observed to regurgitate partially digested food, and after submitting it to a rude kind of mastication by its enormous beak, again to swallow it.

The œsophagus possesses an external cellular covering, a muscular coat, an internal vascular tunic, and a cuticular lining. The muscular coat consists of two layers of fibres; in the external stratum they are transverse (*a*, *fig.* 159), in the internal longitudinal (*b*, *fig.* 159); the reverse of the arrangement observed in the human subject.

Ingluvies.—In those birds which are omnivorous, as the Toucans and Horn-bills, in the frugivorous and insectivorous birds, and in most of the *Grallatores*, which find their food in tolerable abundance, and take it in small quantities without any considerable inter-mission, it passes at once to the stomach to be there successively digested, and the gullet presents no partial dilatations to serve as a temporary reservoir or macerating receptacle. But in the larger Raptorial Birds, as the Eagles and Vultures, which gorge themselves at uncertain intervals from the carcasses of bulky prey, the œsophagus does not preserve a uniform width, but undergoes a lateral dilatation anterior to the furculum at the lower part of the neck. This pouch is termed the *ingluvies* or crop (*b*, *fig*. 156).

Fig. 156.

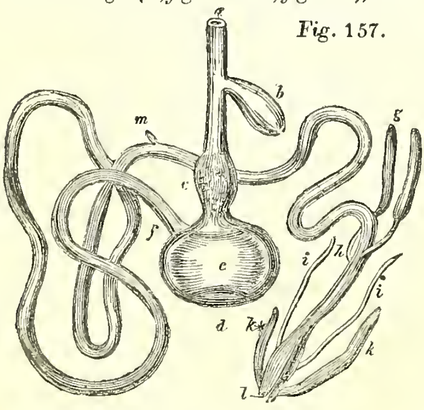


Digestive canal of an Eagle.

In those birds, again, the food of which is exclusively of the vegetable kind, as grains and seeds, and of which consequently a great quantity must be taken to produce the adequate supply of nutriment, and where the cavity of the gizzard is very much diminished by the enormous thickness of its muscular coat, the crop is more developed, and takes a more important share in the digestive process. Instead of a gradual cylindrical lateral dilatation of the gullet, it assumes the form of a globular or oval receptacle appended to that tube, and rests upon the elastic fascia which connects the clavicles or two branches of the furculum together.

In the common Fowl the crop is of large size and single (*b*, *fig*. 157 : *I*, *fig*. 171), but in the Pigeon it is double, consisting of two lateral oval cavities (*b c*, *fig*. 158).

Fig. 157.



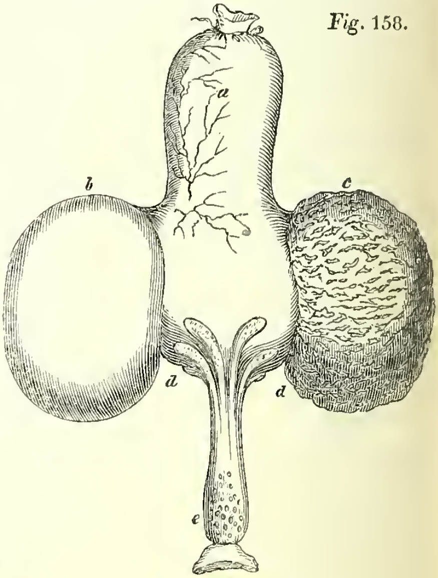
The dilatation of the œsophagus to form the crop is more gradual in the Ducks than in the Gallinaceous birds. The crop is wanting in the Swans and Geese.

The disposition of the muscular fibres of the crop is the same as in the œsophagus, but the muciparous follicles of the lining membrane are larger and more numerous. This difference is most conspicuous in the ingluvies of the granivorous birds, where it is not merely a temporary reservoir, but in which the food is mixed with the abundant secretion of the glands, and becomes softened and macerated, and prepared for the triturating action of the gizzard and the solvent power of the gastric secretion.

The change which the food undergoes in the crop is well known to bird-fanciers. If a Pigeon be allowed to swallow a great quantity of peas, they will swell to such an extent as almost to suffocate it.

The time during which the food remains in the crop depends upon its nature. In a common Fowl animal food will be detained about eight hours, while half the quantity of vegetable substances will remain from sixteen to twenty hours, which is one among many proofs of the greater facility with which animal substances are digested. Mr. Hunter made many interesting observations on the crop of Pigeons, which takes on a secreting function during the breeding season, for the purpose of supplying the young pigeons in the callow state with a diet suitable to their tender condition.* An abundant secretion of a milky fluid of an ash-grey colour, which coagulates with acids and forms curd, is poured out into the crop and mixed with

Fig. 158.



Crop of a Pigeon.

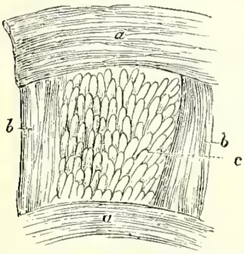
* Animal Economy, p. 235.

the macerating grains. This phenomenon is the nearest approach in the class of Birds to the great characteristic function, the presence of whose special apparatus, the mammæ, has afforded the universally recognized title of the higher division of warm-blooded Vertebrata; and the analogy of the 'Pigeon's milk' to the lacteal secretion of the mammalia has not escaped popular notice. In the subjoined figure one side of the crop (*b*), shows the ordinary structure of the parts, the other (*e*), the state of the cavity during the period of rearing the young (*fig.* 158).

The canal which is continued from the ingluvies to the stomach was called by Hunter the second or lower œsophagus; at its commencement it is narrower and more vascular than that part of the gullet which precedes the crop, but gradually dilates into the first or glandular division of the stomach, which is termed the 'proventriculus' (*ventriculus succenturiatus, bulbus glandulosus, echinus, infundibulum*, the 'cardiac cavity' of Home), (*c, fig.* 156, 157, 166).

In birds with a wide œsophagus (*a, fig.* 165), as the omnivorous and piscivorous tribes, the commencement of the proventriculus (*e, fig.* 165), is not indicated by any change in the direction or diameter of the tube, but only by its greater vascularity, by the difference in the structure of the lining membrane, and by the stratum of glands which open upon its inner surface, and which are its essential characteristic (*c. fig.* 159). Hence it is by some comparative anatomists regarded as a part of the œsophagus.

Fig. 159.



Part of the proventriculus of a Swan dissected.

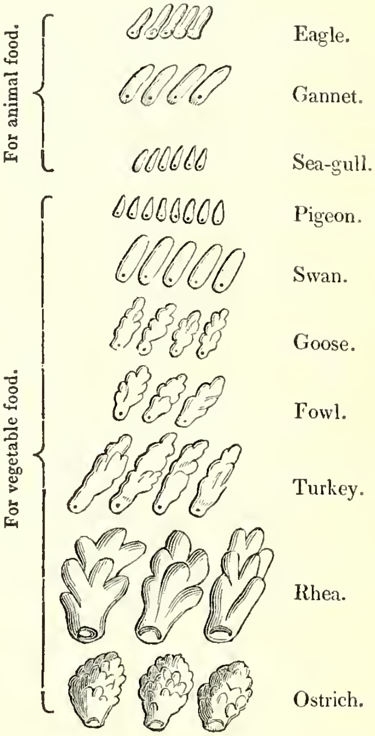
The proventriculus varies, however, in form and magnitude in different birds. In the *Rasores* it is larger than the œsophagus, but much smaller than the gizzard. In the *Psittacidæ* and *Ardeidæ* (Parrot and Stork tribe) it is larger than the gizzard and of a different form. In the Ostrich the proventriculus is four or five times larger than the triturating division of the stomach, being continued down below the liver, and then bent up upon itself towards the right side before it terminates in the gizzard, which is placed on the right and anterior part of this dilatation.

The experiments of Reaumur, Spallanzani, and Hunter, and those of Tiedemann and Gmelin, prove that the secretion of the proventricular or gastric glands is analogous to the gastric juice in man and mammalia.

In the majority of birds the gastric follicles are simple, having no internal cells, dilated fundus, or contracted neck; but from their external blind extremity proceed with an uniform diameter to their internal orifice. This form obtains in the zoophagous and omnivorous birds. In the Dove-tribe the follicles are of a conical shape. In the Swan they are tubuliform; in the Goose and Turkey they present internal loculi; in the Ostrich and Rhea these loculi are so developed that each gland forms a racemose group of follicles, terminating by a common aperture in the proventriculus.

The subjoined figures from Home's Comparative Anatomy (vol. ii. pl. lvi.) show the different forms of the solvent or proventricular glands in different birds.

Fig. 160.



The gastric glands are variously arranged. Among the *Raptores*, we find them in the Golden Eagle disposed in the form of a broad compact belt; in the Sparrow-Hawk this belt is slightly divided into four distinct portions.

In the *Insessores* the glands are generally arranged in a continuous zone around the proventriculus; but in some of the *Syndactyli*, as the Hornbill, the circle is composed of the blending together of two large oval groups.

Among the *Scansores* the Parrots have the gastric glands disposed in a continuous white circle, which is at some distance from the small gizzard. In the Woodpeckers the glands are arranged in a triangular form, with the apex towards the gizzard. In the Toucan they are dispersed over the whole proventriculus, but are more closely aggregated near the gizzard; the lining membrane of the cavity is reticulate, and the orifices of the glands are in the interspaces of the meshes.

Among the *Rasores* the Pigeon shows its affinity to the Passerine Birds in having the gastric glands of a simple structure, and arranged in a zonular form: they are chiefly remarkable for their large cavity and wide orifice. In the Common Fowl and Turkey the glands are more complex, and form a complete circle.

In the *Cursores* the arrangement of the glands is different in almost every *genus*.

In the Ostrich they are of an extremely complicated structure, and are extended in unusual numbers over an oval space on the left side of the proventriculus, which reaches from the top to the bottom of the cavity, and is about four inches broad.

The Rhea differs from the other Struthious birds in having the solvent glands aggregated into a single circular patch, which occupies the posterior side of the proventricular cavity.

In the Emeu the gastric glands are scattered over the whole inner surface of the proventriculus, and are of large size; they terminate towards the gizzard in two oblique lines.

In the Cassowary the glands are dispersed over the proventriculus with a similar degree of uniformity; but they are smaller, and their lower boundary is transverse.

Among the *Grallatores*, the Marabou, or Gigantic Crane, (*Ciconia Argala* and *Marabou*,) has the nearest affinity to the Rhea in the structure and disposition of the gastric glands; they are each composed of an aggregate of five or six follicles, terminating in the proventriculus by a common aperture; and they are disposed in two compact oval masses, one on the anterior, the other on the posterior surface of the cavity. In the Heron (*Ardea cineria*) the solvent glands are of more simple structure, and are more dispersed over the proventriculus; but still they are most numerous on the anterior and posterior surfaces. In the Flamingo the gastric glands are short and simple follicles, arranged in two large oval groups, which blend together at their edges.

The *Natatores* present considerable differences among themselves in the disposition of the solvent glands. In the Cormorant (*Phalacrocorax carbo*) they are arranged in two circular spots, the one anterior and the other posterior; while in the closely allied genus the *Sula*, or Gannet, they form a complete belt of great width, and consequently are extremely numerous. In this respect the Gannet, or Solan Goose, has a nearer affinity to the Pelecan, with which both birds were generically associated by Linnæus.

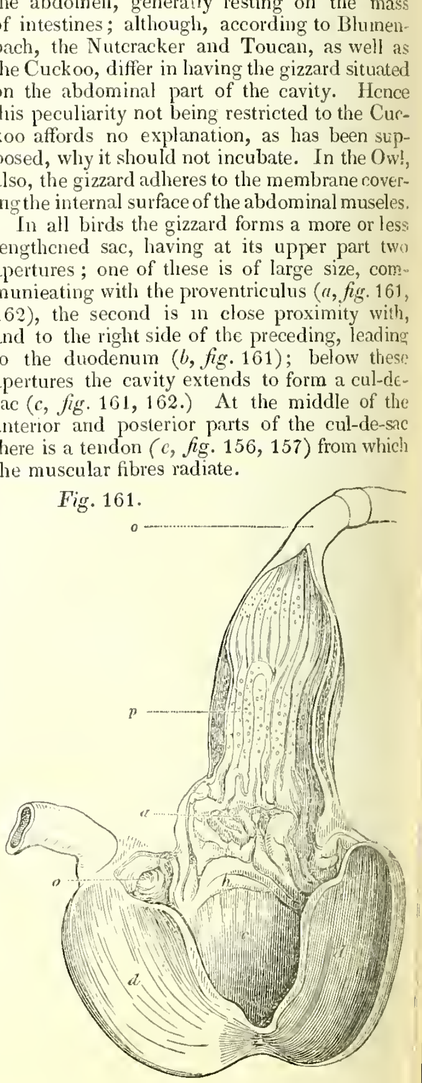
In the Sea-Gulls the gastric glands form a continuous zone; and in the Little Auk (*Alca Alle*) they are spread, according to Sir Everard Home, over a greater proportional extent of surface than in any other bird that lives on animal food, and the form of the digestive organs is peculiar to itself. The cardiac cavity or proventriculus appears to be a direct continuation of the œsophagus, distinguished from it by the termination of the cuticular lining and the appearance of the solvent glands. The cavity is continued down with very gradual enlargement below the liver, and is then bent up to the right side, and terminates in the gizzard. The solvent glands are situated at the anterior or upper part of the cavity every where surrounding it, but lower down they lie principally upon the posterior surface, and where it is bent upwards towards the right side they are entirely wanting. In the graminivorous lamellirostral Water-birds, as the Swan, Goose, &c. the gastric glands have a simple elongated exterior form, but have an irregular or cellular internal surface: they are closely arranged so as to form a complete zone.

In general the muscular or pyloric division of the stomach immediately succeeds the glandular or cardiac division; but in some Birds, as the Auk and Parrots, there is an intervening portion without glands. It is always widely different in structure, and hence has received a distinct name, the 'gizzard' (*gigerium*, *ventriculus bulbosus*).

The *gizzard* is situated below or *sacrad* of the liver, on the left side and dorsal aspect of the abdomen, generally resting on the mass of intestines; although, according to Blumenbach, the Nutcracker and Toucan, as well as the Cuckoo, differ in having the gizzard situated on the abdominal part of the cavity. Hence this peculiarity not being restricted to the Cuckoo affords no explanation, as has been supposed, why it should not incubate. In the Owl, also, the gizzard adheres to the membrane covering the internal surface of the abdominal muscles.

In all birds the gizzard forms a more or less lengthened sac, having at its upper part two apertures; one of these is of large size, communicating with the proventriculus (*a*, *fig.* 161, 162), the second is in close proximity with, and to the right side of the preceding, leading to the duodenum (*b*, *fig.* 161); below these apertures the cavity extends to form a cul-de-sac (*c*, *fig.* 161, 162.) At the middle of the anterior and posterior parts of the cul-de-sac there is a tendon (*c*, *fig.* 156, 157) from which the muscular fibres radiate.

Fig. 161.



Gizzard of a Swan.

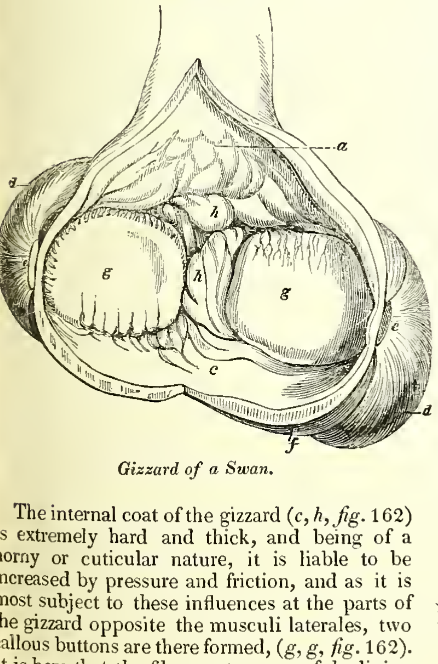
The differences in the structure of the gizzard resolve themselves into the greater or less extent of the tendons, and the greater or less thickness of the muscular coat, and of the lining membrane.

In the *Raptores* the gizzard (*d, fig.* 156) assumes the form of a mere membranous cavity, in accordance with the animal and easily digestible nature of their food. The muscular coat is extremely thin; the fibres principally radiate from small tendons (*e, fig.* 156), and there are some longitudinal fibres beneath the radiating or external layer.

In the *Rasores* and lamellirostral *Natatores* it exhibits the structure to which the term gizzard can be more appropriately applied. The muscular fibres are distinguished by their unparalleled density of texture and deep colour, and are arranged in four masses; two are of a hemispherical form, and their closely-packed fibres run transversely to be connected to very strong anterior and posterior tendons (*e, fig.* 157, 162); they constitute the sides of the gizzard, and are termed the digastric muscles or 'musculi laterales' (*d, fig.* 161, 162): between these, at the end of the gizzard, are the two smaller and thinner muscles called 'musculi intermedii' (*f, fig.* 162). There are likewise irregular bands placed about the circumference of the gizzard.

Fig. 161 shows the relative thickness of the musculi laterales in the gizzard of a Swan, and *fig.* 162 that of the musculi intermedii and tendon.

Fig. 162.



Gizzard of a Swan.

The internal coat of the gizzard (*c, h, fig.* 162) is extremely hard and thick, and being of a horny or cuticular nature, it is liable to be increased by pressure and friction, and as it is most subject to these influences at the parts of the gizzard opposite the musculi laterales, two callous buttons are there formed, (*g, g, fig.* 162). It is here that the fibrous structure of the lining membrane can be most plainly seen:—and it is worthy of observation that the fibres are not perpendicular to the plane of the muscles but oblique, and in opposite directions, on the two sides. Elsewhere the cuticular lining is disposed in ridges and prominences (*h, fig.* 161, 162), which vary in different birds, but are pretty constant in the same species. Carus* has recently figured the gizzard of a Petrel (*Procellaria glacialis*), the lining membrane of which is disposed in a pavement of small square tubercles, like the gastric teeth of some Mollusca.

The cavity of the gizzard is so encroached upon by the grinding apparatus, that it is necessarily very small, the two horny callosities having their internal flat surfaces opposed to one another, like 'millstones.' A crop is as essential an appendage to this structure as the 'hopper' to the mill; it receives the food as it is swallowed, and supplies it the gizzard in small successive quantities as it is wanted.†

Between the stomach of the carnivorous Eagle, and that of the graminivorous Swan, there are numerous intermediate structures, but it is necessary to observe that the animal or vegetable nature of the food cannot always be predicated of from the different degrees of strength in the gizzard. Hard-coated coleopterous insects, for example, require thicker parietes for their due comminution than pulpy succulent fruits.

In the subgenus *Euphones*, among the Tanagers, the muscular or pyloric division of the stomach is remarkably small and not separated from the duodenum by a narrow pylorus.‡

The parietes of the gizzard, like those of other muscular cavities, become thickened when stimulated to contract on their contents with greater force than usual. In the Hunterian collection this fact is well illustrated by preparations of the gizzard of the Sea-gull in the natural state, and that of another Sea-gull which had been brought to feed on barley. The digastric muscles in the latter are more than double the thickness of those in the Sea-gull which had lived on fish.§

The immediate agents in triturating the food are hard foreign bodies, as sand, gravel, or pebbles. The well-known habit in the granivorous birds of swallowing stones with their food has been very differently explained. Blumenbach observes that 'Cæsalpinus considered it rather as a medicine than as a common assistance to digestion; Boerhaave, as an absorbent for the acid of the stomach; Redi, as a substitute for teeth; Whytt, as a mechanical irritation, adapted to the callous and insensible nature of the coats of the stomach.' Spallanzani rejected all supposition of design or object, and hazarded the stupid observation that the stones were swallowed from mere stupidity.

* Tabulæ Anatomiam Comparativam illustrantes, fol. pars iv. 1835.

† Thus we find in Parrots, where the gizzard is remarkably small, that a crop is present. A like receptacle exists also in the Flamingo, in which the gizzard is small but strong.

‡ Carus ut supra, tab. vi. fig. iv.

§ See Home, Comp. Anatomy, vol. i. p. 271, and Hunter, Animal Œconomy, p. 221, where it is related that a similar change was effected by changing the food of a tame Kite.

Pigeons, however, are known to carry gravel to their young. Gallinaceous birds grow lean if deprived of pebbles; and no wonder, since experiment* shows that unless the grains of corn are bruised, and deprived of their vitality, the gastric juice will not act upon or dissolve them. The observations and experiments of Hunter have completely established the rationality and truth of Redi's opinion, that the pebbles perform the vicarious office of teeth.

Hunter inferred from the form of hair-balls occasionally found in the stomach of Cuckoos,† that the action of the great lateral muscles of the gizzard was rotatory. Harvey appears to have first investigated, by means of the ear, as it were in anticipation of the art of auscultation, the actions which are going on in the interior of an animal body, in reference to the motions of the gizzard. He observes, (*De Generatione Animalium, in Opera Omnia*, 4to. p. 208,) "Falconibus, aquilis, aliisque avibus ex preda viventibus, si aurem prope admoveris dum ventriculus jejunus est, manifestos intus strepitus, lapillorum illuc ingestorum, invicemque collisorum percipias." And Hunter observes, (*Animal Œconomy*, p. 198,) "the extent of motion in grindstones need not be the tenth of an inch, if their motion is alternate and in contrary directions. But although the motion of the gizzard is hardly visible, yet we may be made very sensible of its action by putting the ear to the sides of a fowl while it is grinding its food, when the stones can be heard moving upon one another."

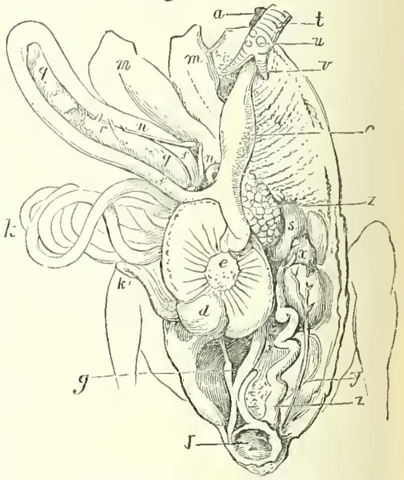
Tiedemann believes that the muscles of the gizzard are in some degree voluntary, having observed that when he placed his hand opposite the gizzard, its motions suddenly stopped.

The pyloric orifice of the gizzard is guarded by a valve in many birds, especially in those which swallow the largest stones. This valve in the Ostrich is formed by a rising of the cuticle divided into six or seven ridges, which close the pylorus like a grating, and allow only stones of small size to pass through. In the *Touraco* the pylorus projects into the duodenum in a tubular form. There is a double valve at the pyloric orifice in the Gannet, and a single large valvular ridge at the same part in the Gigantic Crane. In this species and some other Waders, as the Heron and Bittern; also in the Pelecan, and, according to Cuvier, in the Penguin and Grebe, there is a small but distinct cavity interposed between the gizzard and intestine. An analogous structure is found in the Crocodile.

The *intestines* reach from the stomach to the cloaca; in relative length they are much shorter than in the mammalia. In the Toucan, for example, the whole intestinal canal scarcely equals twice the length of the body, including the bill. The canal is divided into small and large intestines, sometimes by an internal valve, sometimes by the insertion of a single cæcum, but most generally by those of two cæca, which are always opposite to one another. In a few instances there is no such distinction. The small intestines and cæca are longest in the vegetable feeders. The large intestine is, with one or two exceptions, very short and straight in all birds.

The course of the small intestine varies somewhat in the different orders of Birds; it is always characterized by the elongated fold or loop made by the duodenum, (*f f*, *fig.* 163,)

Fig. 163.



Abdominal viscera of a Pigeon.

which fold receives the pancreas (*q q*) in its concavity.

In the *Raptores* the intestines are generally disposed as follows:—

The duodenum forms a long and broad fold, the lower part of which is commonly bent or doubled upon itself: the intestine then passes backwards on the right side of the abdomen, crosses to the left, and is disposed in deep folds upon the edge of a scolloped mesentery; towards its termination the ileum passes up behind the stomach and adheres to it, having here but a narrow mesentery; then passing down the posterior part of the abdomen the ileum makes another loose fold and ends in the rectum, which is continued straight to the cloaca.* In the Owls the last fold of the ileum is nearly as long as the duodenal fold, and the cæca adhere to each side of the fold.

In the *Diurnal Raptores* the intestinal canal

* Grains of barley, inclosed in strong perforated tubes, pass through the alimentary canal unchanged. Dead meat, similarly introduced into the gizzard, is dissolved.

† The hairs of caterpillars devoured by this bird are sometimes pressed or stuck into the horny lining of the gizzard, instead of being collected into a loose ball. They are then neatly pressed down in a regular spiral direction, like the nap of a hat, and have often been mistaken for the natural structure of the gizzard. One of these specimens exhibited as such to the Zoological Society was sent to me for examination, when, upon placing some of the supposed gastric hairs under the microscope, they exhibited the peculiar complex structure of the hairs of the larva of the Tiger-moth *(Arctia Caja)*, and the broken surface of the extremity which was stuck into the cuticular lining was plainly discernible. See *Proceedings of Zool. Soc.* 1834, p. 9.

* In *fig.* 156 the intestines are not represented according to their natural arrangement.

is only twice the length of the body, except in the fish-eating Osprey, in which the intestines are very narrow, and are to the length of the bird itself as eight to one.

In the *Insessores* the scolloped folds of the small intestine are narrower and longer than in the *Raptores,* and the ileum generally adheres to the duodenal mesentery and pancreas instead of to the stomach, prior to passing down to form its last fold and to terminate in the rectum. In the Raven the small intestines are disposed at their commencement in concentric folds.

Among the *Scansores* the Cuckoo presents the following disposition of the intestinal canal: after the usual long and narrow duodenal fold, the ileum* makes a fold which is widened at the end, it then forms a close fold upon itself, at the termination of which the rectum commences. In the Maccaw the course of the small intestine is somewhat peculiar: after forming the duodenal fold, it is disposed in three distinct packets of folds: the intestine, after forming the first two, passes alternately from one to the other, describing shorter folds upon each; it then forms the third distinct fold, which is a long one, at the termination of which the ileum adheres closely to the right side of the gizzard, and then passes backwards and dilates into the rectum.

In the *Rasores* the Dove-tribe have the small intestines disposed in three principal folds; the first is the duodenal fold *(f f, fig.* 163); the second is a long and narrow fold, coiled and doubled upon itself, with the turns closely connected together, *(k, fig.* 163); the third is also a long fold, which is bent or twisted, *(k', fig.* 163.) In the common Fowl the duodenum is disposed in a long simple loop; the ileum passes towards the left, and is disposed in loose folds on the right and lower edge of the mesentery; the ileum before its termination passes up behind the preceding folds, and is accompanied as far as the root of the mesentery by the two cœca, which there open into the commencement of the large intestine.

The Ostrich presents the most complicated course of the intestinal canal in the whole class of birds. The duodenal fold is about a foot in length, and the returning part makes a bend upon itself before it reaches the pylorus; the intestine then turns down again behind the duodenal folds and gradually acquires a wider mesentery. The ileum after a few folds ascends towards the left side, accompanied by the two long cœca, and becomes again connected with the posterior part of the duodenal mesentery; beyond which the cœca enter the intestine behind the root of the mesentery, and the large intestine commences. This part differs from the rectum in other birds in its great extent, being nearly double the length of the small intestines, and being disposed in folds upon a wide mesentery. It terminates by an oblique valvular aperture in a large urinary receptacle. In the Bustard the rectum is a foot in length, which is the nearest approach to the Ostrich which the rest of the class make in this respect.

The small intestines in the *Grallatores* are characterized by their small diameter and long and narrow folds; these are sometimes extended parallel to one another, as in the Crane and Coot; or folded concentrically in a mass, as in the Curlew and Flamingo. In the latter species the duodenal fold is four inches in length; then the small intestines are disposed in twenty-one elliptical spiral convolutions, eleven descending towards the rectum and ten returning towards the gizzard in the interspaces of the former.

Many of the *Natatores* present a concentric disposition of the folds of the small intestines similar to the Flamingo. Home* has given figures of this structure in the intestines of the Sea-mew *(pl.* cviii.); the Gannet or Solan Goose *(pl.* cvi.); and the Goose *(pl.* cxi.). It likewise obtains in the Pelecan and Cormorant.

The arrangement of the muscular fibres of the intestine is the same as in the œsophagus, the external layer being transverse, the internal longitudinal.

The villi of the lining membrane manifest an analogy with the covering of the outer skin, being generally much elongated, so as to present a downy appearance when viewed under water. There are, however, great varieties in the shape and length of the villi. In the Emeu they consist of small lamellæ of the lining membrane folded like the frill of a shirt. In the Ostrich the lamellæ are thin, long, and numerous. In the Flamingo they are short and arranged in parallel longitudinal zig-zag lines.

In many birds a small diverticulum is observed in the small intestine, which indicates the place of attachment of the pedicle of the yolk-bag in the embryo (*m, fig.* 157). We have found this process half an inch in length in the Gallinule, and situated seventeen inches from the pylorus. In the Bay Ibis *(Ibis falcinella)* the vitelline cœcum is an inch in length.

The birds in which the *cœca coli* have been found wanting are comparatively few, though such examples occur in all the orders. These exceptions are most frequent among the *Scansores,* in which the cœca are absent in the Wrynecks, the Toucans, the Touracos, the Parrot tribe, and according to Cuvier in the Woodpeckers.† In the *Insessores* the cœca are deficient in the Hornbill and the Lark. Among the *Grallatores,* we have found them wanting in a Spoonbill. In the *Natatores* they are absent in the Cormorant. The Herons, Bitterns, and, occasionally, the Grebes afford the rare examples of a single cœcum, which is also remarkably short.

In the *Raptores* the diurnal and nocturnal tribes differ remarkably in the length of the cœca. They are each less than half an inch in length in the Eagles and Vultures, but are occasionally wanting in the latter. Cuvier states

* There is seldom any part of the small intestine empty so as to merit the name of *jejunum.*

* Comparative Anatomy, vol. ii.

† In the Poppinjay *(Picus viridis,* Linn.) we have found two small cœca, so closely adhering to the intestine as easily to be overlooked.

that the cœca are deficient in the greater part of the Diurnal Raptores, but we have observed them in the *Haliætus Albicilla*, *Aquila Chrysaetos*, *Astur palumbarius*, and *Buteo nisus*. They seldom exceed the length above-mentioned (*g, fig.* 156), and in the Secretary Vulture they form mere tubercles. In the Barn Owl the cœca severally measure nearly two inches in length, and are dilated at their blind extremities; they are proportionally developed in the larger *Strigidæ*.

In the *Insessores* they are invariably very short where present. Among the *Scansorial Genera* which possess the cœca, these parts are found to vary in length, measuring in the Cuckoo and Wattle-bird (*Glaucopis*), each half an inch; while in the *Scythrops*, or New-Holland Toucan, the cœca are each two inches long, and moderately wide.

In the *Rasores* the cœca present considerable varieties. In the Pigeons (*g, fig.* 163) they are as short as in the Insessorial order, and are sometimes wanting altogether, as in the Crown-pigeon. In the Guan (*Penelope cristata*) each cœcum is about three inches in length; while in the Grouse each cœcum measures a yard long, being thus upwards of three times the length of the entire body. The internal surface of these extraordinary appendages to the alimentary canal is further increased in the Grouse by being disposed in eight longitudinal folds, which extend from their blind extremities to within five inches of their termination in the rectum. We have always found the cœca in this species filled with a homogeneous pultaceous matter without any trace of the heather buds, the remains of which are abundant in the fœcal matter contained in the ordinary tract of the intestines.

In the Peacock the cœca measure each about one foot in length; in the Partridge about four inches; in the common Fowl and other *Phasianidæ* the cœca are each about one-third the length of the body; they commence by a narrow pedicle, which extends about half their length, and then they begin to dilate into reservoirs for the chyme (*g, fig.* 157).

In the *Cursores* the cœca again present very different degrees of development. In the Emeu they are narrow and short. In the Cassowary they are wholly deficient; while in the Ostrich they are wide and upwards of two feet in length, and their secreting and absorbing parietes are further increased by being produced into a spiral valve, analogous to that which exists in the long cœcum of the Hare and Rabbit.

In the *Grallatores* the two cœca are generally short where present; they attain their greatest development in this order in the Demoiselle, where the length of each cœcum is five inches; and they are also large in the Flamingo, where they each measure nearly four inches, and are dilated at their extremities, presenting with the gizzard, crop, lamellated beak, and webbed feet, the nearest approach to the *Anatidæ* of the following order.

In the *Natatores* the cœca, where they are present, vary in length according to the nature of the food, being very short in the fish-eating Penguin, Pelecan, Gull, &c. and long in the Duck, Goose, and other vegetable feeding *Lamellirostres*.

In the crested Grebe (*Podiceps cristatus*), Yarrell detected two cœca, each measuring 3-16ths of an inch in length. In the Canada Goose the same indefatigable observer found the cœca each nine inches in length, and in the White-fronted Goose the same parts measured severally thirteen inches. They have the same length in the Black Swan. In the Wild Swan the cœca measure each ten inches in length, while in the tame species they are each fifteen inches long.

As digestion may be supposed to go on less actively in the somnolent, night-flying Owls, than in the high-soaring Diurnal Birds of Prey, an additional complexity of the alimentary canal for the purpose of retaining the chyme somewhat longer in its passage, might naturally be expected; and the enlarged cœca of the Nocturnal Raptores afford the requisite adjustment in this case. For, although the nature of the food is the same in the Owl* as in the Hawk, yet the differences of habit of life call for corresponding differences in the mechanism for its assimilation.

In the *Rasorial Order*, where the nature of the food differs so widely from that of the Birds of Prey, the principal modification of the digestive apparatus obtains in the more complex structure of the crop, proventriculus, and above all the gizzard; but with respect to the cœca, as great differences obtain in their development as in the *Raptores*. Now these differences are explicable on the same principle as has just been applied towards the elucidation of the differences in the size of the cœca in the *Raptores*. Where the difference in the locomotive powers is so great in the Dove-tribe and the common Fowl; where the circulating and respiratory systems must be so actively exercised to enable the Pigeon to take its daily flights and in some species their annual migrations—a less complicated intestinal canal may naturally be supposed with such increased energy in the animal and vital functions to do the business of digestion, than in the more sluggish and terrestrial vegetable feeders; and accordingly we find that the requisite complexity of the intestinal canal is obtained by an increased development of the cœcal processes in them, while in the *Columbidæ* the cœca remain as little developed as in the *Insessores*, which they resemble in powers of flight. If we regard the cœca as excretive organs, their differences in the above orders may be in like manner explained by their relations to the locomotive and respiratory functions.

In the *Cursores* the development of cœca seems to have reference to the quantity of food, and the ease with which it may be obtained, according to the geographical position of the species. In the Cassowary, which is a native

* The indigestible parts of the prey of the Owl do not pass into the intestine, but are regularly *cast* or regurgitated from the stomach; the length of the cœca cannot, therefore, be accounted for on Macartney's supposition of their being receivers of those parts.

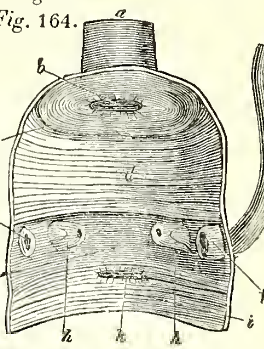
of the fertile districts of a tropical country, vegetable food of a more easily digestible nature may be selected, and it need not be detained unnecessarily long, where a fresh supply can be so readily procured. But in the Ostrich, which dwells amidst arid sands and barren deserts, every contrivance has been adopted in the structure of the digestive apparatus to extract the whole of the nutritious matter of the food which is swallowed.

In the *Grallatores*, where no material differences of locomotive powers or means of obtaining food exist, the cœca present in their development a direct relation to the nature of the food, and are most developed in the *Gruidæ*. The same holds good in the *Natatores*.

Why the increased extent of intestinal surface in the above different cases should be chiefly obtained by the elongation of the cœca, will appear from the following considerations. In consequence of the stones and other foreign bodies which birds swallow, it is necessary that there should be a free passage for these through the intestinal canal, which is therefore generally short and of pretty uniform diameter. In the Omnivorous birds of the tropics, as the Hornbills, Toucans, Touracos, and Parrots, which dwell among ever-bearing fruit-trees, the rapid passage of the food is not inconsistent with the extraction of a due supply of nourishment, but is compensated by the unfailing abundance of the supply. But where a greater quantity of the chyle is to be extracted from the food, and where, from the nature of the latter, a greater proportion of foreign substances is required for its trituration,—while the advantages of a short intestinal tract are obtained, the chyme is at the same time prevented from being prematurely expelled by the superaddition of the two cœcal bags which communicate with the intestines by orifices that are too small to admit pebbles or undigested seeds, but which allow the chyme to pass in. Here, therefore, it is detained, and chylification assisted by the secretion of the cœcal parietes, and the due proportion of nutriment extracted.

The large intestine is seldom more than a tenth part of the length of the body, and, except in the Ostrich and Bustard, is continued straight from the cœca to the cloaca; it may therefore be termed the rectum rather than the colon. It is usually wider than the small intestine, and its villi are coarser, shorter, and less numerous. The rectum (*a*, *fig.* 164) terminates by a valvular circular orifice (*b*), in a more or less dilated cavity, which is the remains of the allantois, and now forms a rudimental urinary bladder, (*c d*). The ureters (*h h*), and efferent parts of the generative apparatus (*f*, *g*,) open into a transverse groove at the lower part of the urinary dilatation, and beyond this is the external cavity which lodges, as in the Reptiles and Marsupial and Monotrematous Quadrupeds, the anal glands and the exciting organs of generation. The anal follicles in Birds are lodged in a conical glandular cavity, which communicates with the posterior part of the outer compartment of the cloaca, and has obtained from its discoverer the name of *Bursa Fabricii* (*k*). Berthold considers this part as a subdivision of the urinary bladder in Birds, and Geoffroy St. Hilaire as the analogue of Cowper's glands.

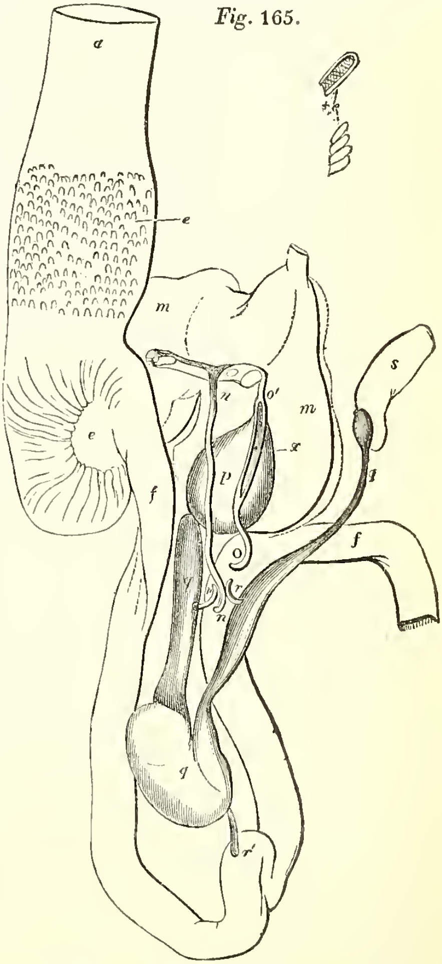
Fig. 164.



Cloaca of the Condor.

Digestive glands. — The *liver* is large in Birds, and proportionally larger in the Aquatic species than in Birds of Prey. In the former

Fig. 165.



Posterior view of the biliary and pancreatic duc in the Hornbill.

it bears a proportion of one-tenth, in some of the latter of one-twenty-ninth part of the entire body.

The liver *(m m, fig.* 163, 165) is situated a little above the middle of the thoracic-abdominal cavity, with its convex surface towards the abdominal parietes, and its concavity turned towards the subjacent viscera: the right lobe covers the duodenum, pancreas, and part of the small intestines; the left lobe covers the proventriculus and part of the gizzard; and the apex of the heart is received between the upper ends of these principal lobes. The liver is, as it were, moulded upon all these parts, and presents corresponding depressions where it comes in contact with them.

It is generally divided into two nearly equal lobes, which are often separated for a short extent, and connected together by a narrow isthmus of the glandular substance. In some birds, however, as in the Pigeon, Cormorant, Swan, and Goose, there is a third, smaller lobe, situated at the back of the liver between the lateral lobes, which from its situation appears analogous to the lobulus Spigelii of Mammalia. In the Common Fowl the left lobe is occasionally cleft so deeply as to form two lobes on that side. In some species the right lobe exceeds the left in size; this is most remarkable in the Bustard, in which the right lobe extends into the pelvis. In the Eagle, however, the left lobe has been observed to be the largest. Each lobe is invested by a double membranous tunic, one embracing it closely, the other surrounding it loosely, like the pericardium of the heart. They are formed by laminæ of the peritoneum, which seems to split at the exterior thin edge of the liver into four layers, two being continued upon the anterior and posterior surfaces adhering to them, the other two forming the loose exterior capsule.

The principal ligament of the liver is formed by a large and strong duplicature of the peritoneum, which divides the abdomen longitudinally like the thoracic mediastinum in Mammalia. It is reflected from the linea alba and middle line of the sternum upon the pericardium, and passes deeply into the interspace of the lobes of the liver; it is attached to these lobes through their whole extent, and connects them below to the gizzard on one side and to the duodenal fold on the other: the lateral and posterior parts of the liver are attached to the contiguous air-cells; and the whole viscus is thus kept steady in its situation during the rapid and violent movements of the bird. The ligament first described is analogous to the falciform ligament of Mammalia; and, although there is no free margin inclosing a round ligament, yet the remains of the umbilical vein may be traced within the duplicature of the membranes forming the septum. As the muscular septum between the thorax and abdomen is wanting, there is consequently no coronary ligament; but the numerous membranous processes which pass from the liver to the surrounding parts amply compensate for its absence.

The liver is of a lighter colour in Birds of flight than in the heavier Water-fowl. Each lobe has its hepatic artery and vena portæ. The hepatic arteries are proportionally small, but the portal veins are of great size, being formed not only by the veins of the intestinal canal, pancreas, and spleen, but also by the inferior emulgent and sacral veins. The blood, which has circulated in the liver, is returned to the inferior cava by two venæ hepaticæ. There are occasionally some smaller hepatic veins in addition to the two principal ones. The coats of the portal and hepatic veins appear to be equally attached to the substance of the liver.

The biliary secretion is carried out of the liver by two and sometimes three ducts; one of these terminates directly in the intestine, and is a 'hepatic duct' (*n, n, fig.* 165); the other enters the gall-bladder, and is a 'cyst-hepatic duct' (*o′, fig.* 165); the cystic bile is conveyed to the duodenum by a 'cystic duct' *(o, fig.* 165). Where, as in a few instances, the gall-bladder does not exist, both hepatic ducts terminate separately in the duodenum (*n, n, fig.* 163); but in no case is there a single ductus communis choledochus as in Mammalia.

The *gall-bladder (p, fig.* 165) is situated near the mesial edge of the concave or under side of the right lobe, and is commonly lodged in a shallow depression of the liver; but sometimes, as in the Eagle, Bustard, and Cormorant, only a very small part of the bag is attached to the liver. It has the same structure as in Mammalia, manifesting no visible muscular tunic, and having its inner surface delicately reticulated.

The gall-bladder is present in all the *Raptores, Insessores,* and *Natatores.* It is wanting in a great proportion of the *Scansores,* as in the Genus *Rhamphastos* and in the whole of the *Psittacidæ* and *Cuculidæ.* Among the *Rasores* the gall-bladder is constantly deficient in the *Columbidæ* or Dove-tribe alone, in which the cœca are shorter than in any other vegetable feeder: *(n n, fig.* 163, are the two hepatic ducts terminating apart from one another in the Pigeon.) The gall-bladder is occasionally absent, according to the French Academicians, in the Guinea-fowl; and they also found it wanting in two out of six Demoiselles *(Anthropoides Virgo).* The gall-bladder is small and sometimes absent in the Bittern: it is always wanting in the Ostrich.

The bile, as before observed, passes directly into the gall-bladder, and not by regurgitation from a ductus choledochus; the cyst-hepatic duct arises from the right lobe, and is continued in some birds along that side of the bag which is in contact with the liver, where it penetrates the coats of the cyst and terminates about one-third from the lower or posterior end. In the Horn-bill we found it passing over the upper end of the bladder to the anterior or free surface, and the cystic duct continued from the point where the cyst-hepatic duct opened into the bladder; so that the cystic duct had a communicaton both with the reservoir and the cyst-hepatic duct; being somewhat analogous to the ductus communis choledochus;

(see *fig.* 165, where *x* represents the orifice by which the bile passes both in and out of the gall-bladder.)

In the Goose the cyst-hepatic duct terminates by a very small orifice, surrounded by a smooth projection of the inner membrane, which, aided by the obliquity of the duct, acts as a valve and prevents any regurgitation towards the liver. The cystic duct here passes abruptly from the posterior extremity of the gall-bladder, which is not prolonged into a neck. The duct makes a turn round the end of the bag, and is so closely applied to it, as to require a careful examination to determine the true place of its commencement.

The hepatic duct (*n*, *fig.* 165) arises by two branches from the large lateral lobes of the liver, which unite in the fissure or ' gates' of the gland. Two hepatic ducts have been found in the Curassow; but these and the cystic duct terminate separately in the duodenum.

The place of termination of the cystic and hepatic duct is generally, as shown in *fig.* 163 and 165, pretty close together at the end of the fold of the duodenum; but in the Ostrich one of the hepatic ducts, which is very large and short, terminates in the commencement of the duodenum about an inch from the pylorus; while the other enters with the pancreatic duct at the termination of the duodenum.

Both the cystic and hepatic ducts undergo a slight thickening in their coats just before their termination; and it is remarkable that, in some of the Marsupiata, as the Kangaroo, the termination of the ductus choledochus is similarly thickened and glandular. The passage of the bile-ducts in birds through the coats of the intestine is oblique, as in the Mammalia, and they terminate upon a valvular prominence of the lining membrane of the gut.

The *Pancreas* (*q*, *q*, *fig.* 163, 165) consists of two and sometimes of three distinct portions in Birds; but these are so closely applied together at some point of their surface as to appear like one continuous gland. It is of a narrow, elongated, trihedral form, lodged in the interspace of the duodenal fold, and generally folded upon itself like the duodenum, as in the Hornbill (*fig.* 165).

The structure of the pancreas is conglomerate, like that of the salivary glands, but the ultimate follicles are differently disposed. In the salivary glands these are irregularly branched, while those of the pancreas in Birds diverge in the same plane from digitated and pinnatifid groups.*

The ducts (*r r*, *fig.* 163, 165) formed by the reiterated union of the efferent branches from the component follicles of the pancreas are in general two in number, which terminate separately in close proximity to the hepatic and cystic ducts; but occasionally there are three pancreatic ducts, as in the common Fowl, Pigeon, Raven, and Horn-bill; in which case the third duct commonly terminates at a distance from the other two: in the Horn-bill it proceeds from an enlarged lobe of the pancreas at the end of the duodenal fold, and entering that part, as at *r'*, *fig.* 165.

* Müller de Gland. Struct. Pen. fol. p. 66.

The *Spleen* (*s*, *s*, *fig.* 163, 165) is comparatively of small size in Birds; it is generally of a round or oval figure, but sometimes presents an elongated and vermiform shape, as in the Sea-Gull, or is broad and flat as in the Cormorant. It is situated beneath the liver, on the right side of the proventriculus. It is, however, somewhat loosely connected to the surroundiug parts, so that its position has been differently described by different authors. We have generally been able to trace a process of the pancreas passing into close contact with it, and connected to it by a continuation of vessels, as in the Horn-bill (*fig.* 165, *q*, *s*), where it has been turned aside to show the hepatic and pancreatic ducts. The texture of the spleen is much closer in Birds than in Mammalia; but a minute examination proves that the blood of the splenic artery is ultimately deposited in cells, from which the splenic veins arise. These veins in the Swan and some other Lamellirostres form a network on the exterior surface of the spleen, as in the Chelonian Reptiles.

Absorbents.—The presumed absence of absorbent vessels in the Oviparous Vertebrata was cited by the supporters of the theory of venous absorption in the time of William Hunter as strong evidence in favour of their views; and the same assertion has again been repeated in the present day by Majendie,* who, in subsequently admitting† the existence of lymphatics in Birds, still contends against their being the exclusive instruments of the function of absorption.

Traces of the lymphatic system in the present class appear to have been observed by Swammerdam‡ as early as 1676, who sent his preparation ' Lymphaticum peculiare ex abdomine Gallinæ' to the Royal Society of London; the lacteals were afterwards noticed in the Stork by Jacobæus§ in 1677, and traces of lymphatics are described by Lang‖ in 1704, and by Martin Lister¶ in 1711. Lymphatic vessels and glands, however, considered as such, according to the Hunterian doctrine of absorption, were first undoubtedly seen by John Hunter in the neck of a Swan, and the lacteals of Birds were afterwards re-discovered by Hewson, who made the first attempt to give a detailed account of the absorbent system in Birds. Our knowledge of this system has since been greatly enlarged by the labours of Tiedemann,** Fohmann,†† Lauth,‡‡ and Panizza.§§

* Journal de Physiol. tom. i. p. 47.
† Annales des Sciences Nat. iii. p. 410.
‡ Birch, Hist. of the Royal Society, iii. p. 312.
§ Anat. Ciconiæ in Acta Hafn. v. p. 247.
‖ Physiologia Lips. fol. p. 99.
¶ Dissertatio de Humoribus, 1711, 8vo. p. 228.
** Anat. und Naturgeschichte der Vögel, tom. i. p. 533.
†† Anat. Untersuchungen über die Verbindung der Saugadern mit den Venen, 1821, p. 136.
‡‡ Annales des Sciences Nat. iii. p. 381.
§§ Osservazione Antropo-Zootomico Fisiologiche, fol. Pavia, 1830.

The species in which the absorbent system has been investigated are the Buzzard, Woodpecker, Turkey, Common Fowl, Bittern, Heron, Stork, Duck, Swan, Wild and Tame Goose, but especially in the latter.

The absorbents of Birds differ from those of Mammals in having fewer valves, which are also less perfect, being so loose as frequently to permit for a certain extent a retrograde passage of the injected fluid. The lacteals, lymphatics, and thoracic ducts have very thin parietes, so as easily to be ruptured, but they are composed, as in Mammals, of two tunics, of which the internal is the weakest.

The lymph resembles that of Mammals, but the chyle differs essentially in its transparency and want of colour. The lacteals have, however, been observed to contain an opake white fluid in a Woodpecker that had been killed after swallowing a quantity of ants.

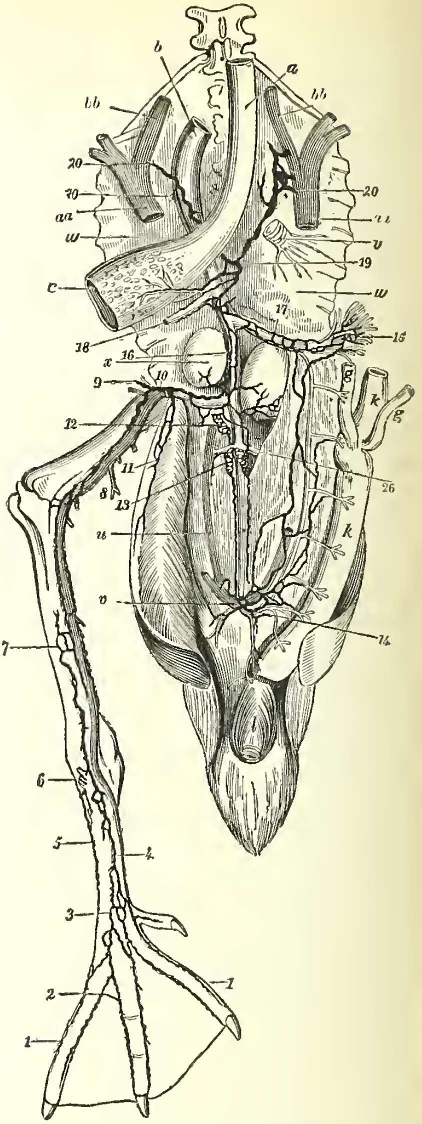
With respect to the disposition of the absorbents, they do not form in Birds two strata, as in Mammals; at least those only have been observed which correspond to the deep-seated absorbents which accompany the large vessels.

The lymphatic glands or ganglions are also much less numerous in Birds than Mammals, being in the former generally restricted in their position to the anterior part of the chest or the root of the neck. In the Penguin, however, a femoral and two axillary absorbent glands have recently been described.* They have the same structure as in Man, but are softer. In other parts of the body the absorbent glands are replaced by plexuses of lymphatic vessels surrounding the principal bloodvessels. It frequently happens, as in Mammalia, that two large absorbents form by their union a trunk, which is of smaller diameter than either of the vessels composing it.

The absorbents of Birds terminate principally by two thoracic ducts, one on either side, which enter the jugular veins by several orifices. But besides these communications, Tiedemann, Fohman, Lauth, and Lippi state that the lymphatic plexuses of the posterior part of the body communicate with the contiguous sacral and renal veins. And Lauth describes several intercommunications in other parts of the body; these, however, are denied by Panizza, whose careful and elaborate researches seem to prove that the passage of the lymph into the venous system takes place in Birds only in two places in the pelvic region in addition to those by the two thoracic ducts in the neck.

The lymphatics of the foot unite to form the vessels which are found running along the sides of each toe (1, 1, *fig.* 166). In the *Palmipedes* there are anastomosing branches which pass from the lateral vessel of one toe to that of the adjoining toe, forming arches in the uniting web (2). These branches form a small plexus (3) at the anterior part of the digito-metatarsal joint, from which three or four lymphatics are continued. The anterior and internal branches (4) accompany the blood-vessels, and form a network around them; the posterior and external branches (5) receive

Fig. 166.



*Absorbents of a Goose.**

the lymphatics of the sole of the foot, then ascend along the metatarsus, and form at its proximal articulation a close network (6); all the vessels then ascend the tibia, forming a plexus (7) around it as far as the middle of the leg; then they unite into two branches, of which the smaller passes along the anterior part of the depression between the tibia and fibula as far as the knee-joint, where it joins the other branch which accompanies the blood-vessels. The trunk formed by the union of the two preceding branches accompanies the femoral vessels, forming plexuses in its course

* Reid, in Proceedings of Zool. Soc. Sept. 1835.

* From Lauth's Monograph, Annales des Sciences Nat. t. iii. pls. 23 and 25.

(8), which receive tributary absorbents from the surrounding muscles, and a large branch (9) corresponding to the deep-seated femoral vessels.

The iliac trunk (10) accompanies the great femoral vein into the abdomen, which it enters anterior to the origin of the pubis; it there receives branches from the lateral parts of the pelvis (11) and afterwards separates into two divisions.

The posterior division receives some lymphatics from the anterior lobes of the kidneys, and those of the ovary or testicles; it communicates anteriorly with a branch from the absorbents which surround the great mesenteric artery, and posteriorly with large vesicular plexuses or receptacles (12, 13) surrounding the aorta and its branches, and which receives the lymphatics from the renal plexus, and those accompanying the arteria sacra media (14).

The sacral or pelvic plexiform vesicles of the lymph are described by Panizza in the Goose as being two in number, situated in the posterior region of the body, in the angle between the tail and the thigh. Each vesicle is little more than half an inch long and a quarter of an inch broad, and is shaped somewhat like a kidney-bean. Panizza laid them bare in several living Geese and punctured them, upon which the lymph issued in considerable quantity, and coagulated into a jelly like the lymph from ordinary lymphatics. Fluids thrown into the lymphatics leading to the vesicles not only filled these cavities, but passed from them into the veins. There are analogous vesicles in the Reptiles, which are endowed with a pulsatile power, and propel their contents into the pelvic veins *per saltum;* but the recent researches of Müller (Archiv. für Physiol. 1834, p. 300) show that the pelvic lymphatic vesicles of Birds are not endowed with a power of motion like that belonging to those of Reptiles, he having satisfied himself, by repeated examination of the living Goose, that the alternate contraction and dilatation of these vesicles in this animal, which Panizza conceived to depend on an automatic power within them, corresponds exactly with the motions of respiration, and no longer continues when they are interrupted.*

The anterior division of the femoral lymphatic trunk (16) accompanies the aorta, upon which it forms a plexus with the branch of the opposite side, and with the intestinal absorbents (15).

These vessels, which from the transparency of their contents can scarcely be termed with propriety 'lacteals,' commence from a plexiform continuous network situated between the mucous and muscular coats of the intestine; they are larger here than when they quit the intestine to pass upon the mesentery. They accompany the branches of the superior mesenteric artery, there being many absorbents for one artery, which by their anastomoses form plexuses surrounding the bloodvessels. Before reaching the aorta, these absorbents communicate with the inferior or posterior division of the femoral trunk, and with the absorbents of the ovary or testicles, after which they pass upon the aorta (16, 17), where they receive the lymphatics of the pancreas and duodenum, and terminate by uniting around the cœliac axis (18) with the lymphatics of the liver, the proventriculus (*c*), the gizzard, and the spleen, forming a considerable plexus, from which, according to Lauth, it is by no means rare to see branches passing to terminate in the surrounding veins.

The aortic plexus (19), which may be regarded as analogous to the receptaculum chyli, always gives origin to two thoracic ducts (20, 20) of varying calibre, but often, as in the Goose, exceeding a line in diameter. They are situated at their origin behind the œsophagus (*a*) and in front of the aorta (*b*); they advance forwards, diverging slightly from each other, pass over the lungs (*w w*), from which they receive some lymphatics, and terminate severally, after being joined by the lymphatics of the wing, in the jugular vein of the same side. The left thoracic duct, before entering the vein, receives the trunk of the lymphatics of the left side of the neck; the right thoracic duct receives only a branch of those of the same side.

The lymphatics of the wing follow the course of the brachial artery, forming a plexus around it, especially at the elbow-joint. Their principal trunk, to which all the collateral branches are united about the upper third of the humerus, is here of large size, but its diameter soon begins to be diminished, and it is very small at the head of the humerus. When it reaches the parietes of the chest, it receives two or three large lymphatics from the pectoral muscles, and a branch which accompanies the brachial plexus. Soon after a small lymphatic gland is sometimes formed on the trunk, which lastly unites with the thoracic duct of its own side.

The lymphatics of the head accompany the branches of the jugular vein, and are readily discerned upon those which are situated between the rami of the lower jaw. They form, by uniting with the cervical absorbents, two lateral branches on each side, which accompany the corresponding jugular vein, being situated, one in front, the other behind that vessel. These lymphatics communicate together, at the anterior and posterior parts of the neck, by transverse or oblique branches. They receive in their progress absorbents from the muscles, and from the peculiar glands which are seen beneath the skin of the neck. The internal branch on the left side receives also a considerable absorbent from the œsophagus. At the lower part of the neck both branches receive a notable branch which accompanies the carotid arteries, and a little further on they form on each side a lymphatic gland situated on the jugular vein. On the right side the trunk of the cervical lymphatics terminates in the jugular vein, after having furnished a communicating branch with the thoracic canal of that side; on the left side it terminates at once in the corresponding thoracic duct.

Vascular system.—*Heart.*—The heart in Birds is divided, as in Mammals, into four

* See Allen Thompson, in Edinb. Med. and Surg. Journ. No. 125.

distinct cavities, which have the same relations to each other, and impress the same course on the circulating fluid.*

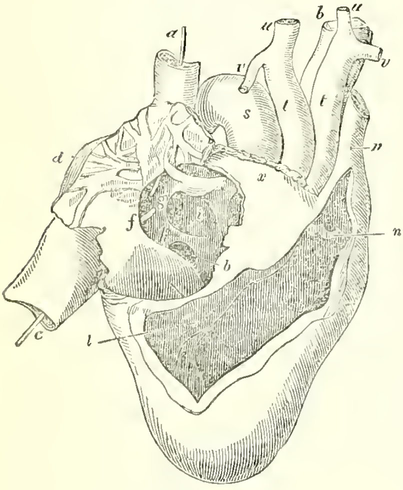
The form of this viscus is always that of a cone, sometimes wide and short, as in the Ostrich and Crane; sometimes more elongated, as in the Emeu (*fig.* 167) and Vulture; or still more acute, as in the Curlew, Common Fowl, &c.

Its situation is more anterior and mesial than in Mammalia, and its axis is always parallel with the axis of the trunk. It is not contained with the lungs in an especial cavity, but its apex is lodged between the lobes of the liver; the diaphragm not being so far developed as to separate the chest from the abdomen.

As the lungs are confined to the dorsal part of the chest, the whole of the anterior surface of the *pericardium* is exposed when the sternum of the bird is removed. The pericardium is thin, but of a firm texture, and adheres by its external surface to the surrounding air-cells. It is of considerable size, and commonly prolonged for some way between the lobes of the liver.

The *auricles* of the heart in Birds have not externally such distinct *appendices* as in Mammals. The right auricle is much larger than the left; it is more distinctly divided internally into a sinus (*d*, *fig.* 167) and auricle proper

Fig. 167.



Heart of the Emeu.

than in Mammals, and these parts are separated by a more complete valvular structure; in which respect Birds bear a closer analogy to Reptiles.

Three veins terminate in the sinus, there being in Birds always two superior cavæ, as in Reptiles. The right superior cava (*a*), which returns the blood from the right wing and right side of the neck, terminates in the upper and anterior part of the sinus; the left superior cava (*b*, *b*) winds round the posterior part of the left auricle to open into the lower part of the sinus; just before its termination it receives the coronary vein, so that this does not open separately into the auricle as in most Mammalia.* The inferior cava (*c*) terminates in the sinus just above the orifice of the left superior cava, and a semilunar valvular fold (*h*), analogous to that of the coronary vein in man, is extended forwards between these orifices so as to separate them, and afford a protection to the mouth of the left superior cava, in addition to that which it derives in common with the other veins from the larger valves at the mouth of the sinus.

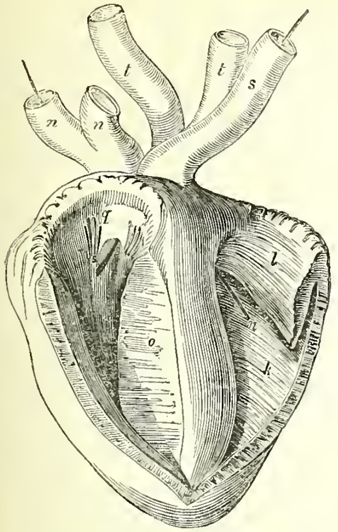
The disposition of the valves between the sinus and auricle seems more especially destined to prevent regurgitation into the sinus, when the pulmonary circulation may be impeded, rather than to impress any definite course on the current of blood flowing through the auricle, as Cuvier supposes. A strong oblique semilunar muscular fold (*g*) commences in the Emeu by a band of muscular fibres running along the upper part of the auricle, and expanding into a valvular form extends along the posterior and left side of the sinus, terminating at the lower part of the fossa ovalis (*i*). A second semilunar muscular valve (*f*), of equal size, extends parallel with the preceding along the anterior border of the orifice of the sinus, its lower extremity being fixed to the smooth floor of the auricle, its upper extremity being continued into a strong muscular column running parallel to the one first mentioned across the upper and anterior part of the auricle, and giving off from its sides the greater part of the *musculi pectinati*. From this structure it results that the more powerfully the musculi pectinati act in overcoming the obstacle to the passage of the blood from the auricle to the ventricle, the closer will the valves be drawn together, and the stronger will be the resistance made by them to the regurgitation of the blood from the auricle into the sinus. The parietes of the auricle in the interspaces of the muscular fasciculi are thin and transparent, consisting in many parts only of the lining membrane of the cavity and the reflected layer of the pericardium blended together. The *fossa ovalis* (*i*) is a deep depression situated behind the posterior semilunar valve, which, we may observe, bears nearly the same relation to the fossa as the annulus ovalis in the human heart. The membranous septum closing the foramen ovale is complete and strong, but thin and semi-transparent. The *appendix auriculæ* (*x*) is the most muscular part of the cavity; it does not project freely in front of the great vessels arising from the ventricles, but is tightly tied down to them by the reflected layer of the pericardium. The auriculo-ventricular orifice is an oblique slit (*k*, *fig.* 169; a bristle is passed through it in *fig.* 167). The manner in which re-

* The blood of Birds differs from that of the other Vertebrate classes in the greater number of globules, and from that of Mammalia in their form, which is oval instead of round. See BLOOD.

* In those Mammalia which approach nearest to the oviparous vertebrata, as the *Monotremata* and *Marsupiata*, there are always two superior cavæ, as in Birds and Reptiles; a similar structure obtains in some of the *Rodentia*, as the Porcupine; and also occurs in the Elephant. In all these cases we have found that the coronary vein terminates in the left superior cava.

gurgitation by this orifiee is prevented is one of the chief peculiarities in the heart of Birds.

Fig. 168.

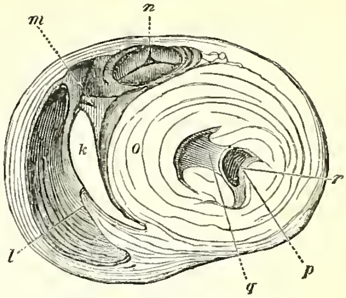


Ventricles of the heart of a Swan.

The right ventricle (*k*, *fig.* 168) is a narrow triangular cavity, applied as it were to the right and anterior side of the left ventricle, but not extending to the apex of the heart. The parietes are smooth, and, except at the septum ventriculorum, they are of pretty uniform thickness, but weaker in comparison to those of the left ventricle than in Mammalia. A number of short fleshy columns extend from the septum to the free parietes of the ventricle at the angle of union of these two parts, leaving deep cells between them; a strong fleshy column (*m*, *fig.* 169) also extends from the right side of the base of the pulmonary artery to the upper extremity of the auriculo-ventricular valve; but these are the only *columnæ carneæ* in the right ventricle; there being none of a pyramidal form projecting into the cavity, nor any *chordæ tendineæ*. The principal valve which guards the auricular aperture is a strong muscular fold (*l*, *fig.* 167, 168, 169), nearly as thick as the walls of the ventricle itself, extending from the fleshy column above mentioned obliquely downwards and backwards to the angle formed between the septum cordis and the wall of the ventricle at the lower and posterior part of the cavity. The free rounded edge of this muscular valve is turned towards the convex projection made by the septum, and must be forcibly applied to this part during the systole of the ventricles, so that, while all reflux into the auricle is prevented, additional impulse is given to the flow of blood through the pulmonary artery; the muscular parietes of the ventricle being thus complete at every part except at the orifice of the artery.

The small muscular column (*m*, *fig.* 169) at the upper part of the auricular orifice is analogous in its position to the single valve which guards the corresponding orifice in Reptiles; in which class the Crocodiles alone present a second muscular valve, which, though small, is

Fig. 169.



Section of the ventricles, Pelecan.

analogous in its position, and evidently a rudimental form of the large muscular valve in Birds.

The right ventricle is remarkable for the smoothness and evenness of its inner surface. The pulmonary artery is provided at its origin with three semicircular valves (*n*, *fig.* 169). It divides, as usual, into two branches (*n*, *n*, *fig.* 168), one for each lung; the right branch passes under the arch of the aorta.

The aerated blood is returned from the lungs by two veins which open into the back part of the left auricle; a strong semilunar ridge, which is hardly sufficiently produeed to be called a valve, divides the cavity of the auricle in which the veins terminate from the muscular part or appendix. The fleshy columns are very numerous and complicated in this part of the auricle, which is closely tied down to the ventricle by the serous layer of the periearдium and dense cellular tissue.

The left ventricle (*o*, *fig.* 168, 169) is an elongated conical cavity, the parietes of which are three times as thick as those of the right ventricle, and exhibit strong fleshy columns extending from the apex towards the base; two of the largest of these columns present in the Emeu a short convex eminence towards the auriculo-ventrieular orifiee (*r*, *fig.* 169), and give off short thick tendons to the margin and ventricular surface of two membranous folds, (*p*, *q*, *fig.* 168, 169) which correspond to the mitral valve in Mammalia. Of these valves, the one next the aorta (*q*) corresponds to the single valve which guards the auricular opening in the heart of Reptiles, and is most developed in Birds; the opposite valve is of much less size. In many Birds the chordæ tendineæ pass from the valves at once to the parietes of the ventricle, and are not attached to columnæ carneæ. The surface of the ventricle formed by the septum is smooth from the orifice of the aorta down to the apex of the heart. The aorta is provided, as in Mammalia, with three semicircular valves. In Reptiles, even in the Crocodile, the great arteries arising from the ventricles are each provided with two valves only.

We have observed that in general the valves at the base of the pulmonary artery were thicker and stronger than those at the origin of the aorta, and our lamented and talented friend Mr. Home Clift discovered some years ago that the extremities of the semilunar valves in Birds were connected to small, firm, and sometimes ossified styles imbedded in the fibrous coat of the vessels.

The arrangement of the muscular fibres of the ventricle in Birds is such that the right ventricle appears to be formed by a partial secession of the outer from the inner layers of the parietes of the left ventricle at the anterior and right side of that cavity. See the transverse section, (*fig.* 169.)

Arteries.—The distribution of the arterial system has been described in a general manner by Cuvier, Tiedemann, and Nitzsch, and has subsequently been very completely elucidated by Barkow in the 12th Volume of Meckel's Archives of Physiology; where the different varieties which various species of birds present in the course of individual arteries are laboriously pointed out. In our own dissections we have been guided by the excellent description long ago given by Dr. Macartney, (*Art.* Birds, Rees' Cyclopædia) which we shall here give verbatim, with some general remarks and additional particulars afforded by the researches of Barkow and our own dissections. The description will be aided by the subjoined beautiful figure taken from Barkow's Monograph (*fig.* 170).

The arterial system in Birds is essentially distinguished from that of Mammals by the following differences:—

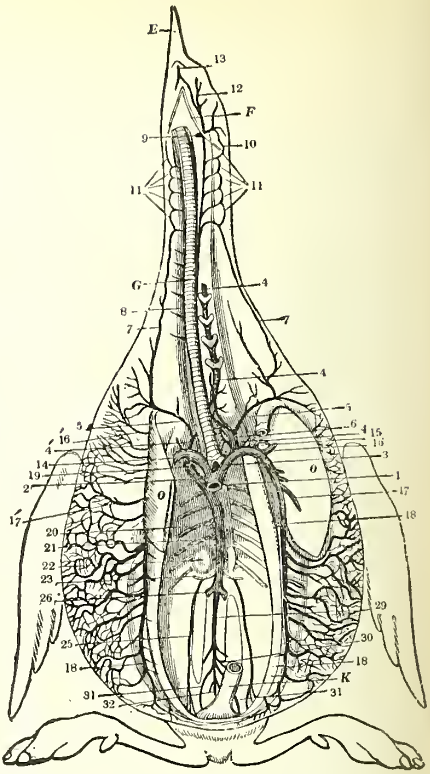
1st. The division of the aorta into three principal branches, almost immediately at its origin.

2d. The course of the arch of the aorta over the right instead of the left bronchus to become the descending aorta.

3d. The origin of the arteries of the posterior extremities, which do not come off from a single branch analogous to the external iliac of Mammalia, but from two arteries which are detached successively from the aorta at a great distance from each other, and pass from the pelvis by two separate apertures.

The arteries of the systemic circulation proceed, Macartney observes, "from a single trunk, which arises from the left ventricle of the heart. This trunk, the aorta, (1, *fig.* 170) is so short that it is concealed by the other parts on the basis of the heart, and is only brought into view after the reflections of the pericardium and the adjoining vessels are detached by dissection. It is from thence that as the parts are commonly beheld, there appear to be three great arteries issuing together from the middle of the heart, which are the primary branches into which the aorta is divided. The first branch is to the left side, and after it is sent off, the trunk affects to turn over the auricle before it gives the branch of the right side; these two branches pass in a curved manner from the heart towards the axilla in the form of horns, and each is analogous to the arteria innominata of the human subject, so that instead of one there may be reckoned two *arteriæ innominatæ* in Birds (*t t*, *fig.* 167, 168). After these branches are parted with, the arterial trunk (*s*, *fig.* 167, 168, 2, *fig.* 170) is continued over the auricles," and the right bron-

Fig. 170.



Arteries of the Trunk, Grebe.

chus, "and, on reaching the back part of the heart, becomes *the descending aorta.*

"The *arteria innominata* (3) first sends off the common trunk of the carotid and vertebral arteries (4), which before its division gives off one or two small branches; one of these runs down upon the lungs in company with the par vagum, and appears to supply branches to the aponeurosis of the lungs, and the air-cells at the upper part of the thorax; the other branch, after supplying the lymphatic gland of the neck with several small arteries, ascends upon the side of the œsophagus, to which, and the inferior larynx, the divisions of the trachea, and to the parts and integuments of the side of the neck, its branches are distributed, anastomosing with the superior œsophageal and tracheal arteries. This branch is often not sent off until the trunk divides into the vertebral and carotid, in which case it comes from the latter artery. Sometimes in the Duck, the *suprascapular* artery, which is usually divided from the vertebral, is a branch of the common trunk."

The *carotid* arteries (4, 4, *fig.* 170, *u u*, *fig.* 167) are frequently of unequal size; in the Dabchick the left is by much the largest; in the Emeu we found it the smallest. "In the Common Fowl, each carotid, after parting from the vertebral artery (6), proceeds to the middle of the neck and soon disappears; becoming covered by the muscles of the anterior part of the neck, and entering the canal formed by the inferior spinous processes of the cervical vertebræ, within which it lies hidden, and in close contact with its fellow of the other side, to very near the head." In the Bittern the two carotids are situated one behind the other, and adhere so intimately together in this situation that they have been erroneously described as a single trunk.

"The carotid artery emerges from between the muscles of the neck, at about the third or fourth vertebra from the head (9); and after giving a branch (10, 11), *Arteriæ cutaneæ colli laterales*, downwards, to the lateral muscles and integuments of the neck, it runs along the outer edge of the rectus major anticus muscle to behind the angle of the jaw, where it divides into its several branches.

"An artery (*arteria occipitalis*) first goes off posteriorly, which passes a little forwards under the branch of the os hyoides, and after sending some blood to the muscles of the neck, makes a turn backwards, enters the foramen in the transverse process of the second vertebra, and terminates by a singular anastomosis in the vertebral artery.*

"The next branch is analogous to the *internal carotid;* it goes forward also under the os hyoides, and passes behind the muscles of the jaws close upon the lower part of the skull, at which place it sends a branch upwards, which appears to penetrate the bones on the outside of the ear, and supply the organ of hearing, sends a branch into the skull and another through the articulation of the jaw, to unite with the ophthalmic, and contribute to the plexus at the back of the orbit (*Rete ophthalmicum* of Barkow). The internal carotid then enters an osseous canal, which runs along the basis of the cranium, between the tables of the bone; and at the lower and back part of the orbit, the artery receives a remarkable anastomosing branch of the internal maxillary, which almost equals in size the carotid itself, and these two vessels produce by their union one which passes almost directly into the cranium at the usual place for the entrance of the carotid artery. This vessel forms within the skull an anastomosis similar to the circle of Willis; but the branch which occupies the place of the *basilar artery* is very small, and appears to be furnished entirely from the anastomosis of the carotids, and designed only to supply the medulla oblongata and spinal marrow. The branches of the internal carotid are thickly spread in an arborescent form upon the surfaces of the brain; some on the outside and others on the internal superficies of the ventricles, and the fissure between the two hemispheres." The orbital plexus formed by the carotid sends off the *inferior palpebral, ethmoidal, lachrymal*, and *ophthalmic* arteries. The ophthalmic artery forms two remarkable plexuses at the posterior part of the globe of the eye; the first is situated close beside the inner side of the optic nerve, and is formed by an artery analogous to the *arteria centralis retinæ*, and gives off the artery to the base of the marsupial membrane; the second plexus is situated more exteriorly, and gives off the ciliary arteries.

"After the trunk of the carotid has sent off the internal carotid, it passes for a little way downwards and forwards behind the angle of the jaw, and divides at once into different branches, corresponding to those of the *external carotid* in mammalia; the first of which might be called the œsophageal or laryngeal artery. This vessel sends a branch to the muscles upon the horn of the os hyoides, and then turns downwards and divides into two branches, one to the trachea (*G, fig.* 170), and the other to the œsophagus, upon the side of which parts they descend to near the thorax," forming a series of arches (11, 11), and ultimately inosculate with the tracheal and œsophageal branches of the common trunk of the carotid and vertebral arteries.

"The external *maxillary artery* (12) dips in between the pterygoid muscle and that which is situated at the back of the lower jaw for opening the mouth; it then passes behind the tympanic bone, and gives twigs upwards to the muscles of the jaws, and to the plexus at the back of the orbit: upon emerging from behind the tympanic bone, it lies under the zygomatic or jugal bone, and sends an artery upwards, which is distributed to the temporal and masseter muscles, and proceeding under the triangular tendon that comes from the inferior margin of the orbit to the lower jaw, it divides into two principal branches; one of these passes along the side of the upper jaw, gives a branch upwards to the fore part of the orbit which unites with the ophthalmic artery, and is lost at the top of the head. This branch is very large in birds with combs, as in conjunction with the ophthalmic, it furnishes numerous vessels to these vascular parts. The artery then goes on and supplies branches to the sides of the head before the orbits, and to the integuments and substance of the upper mandible, inosculating with the palatine branches of the internal maxillary artery. The second portion of the external maxillary proceeds to the lower jaw, to which, and the lower part of the masseter muscle, it is distributed. The external maxillary supplies the place of the *temporal*, *labial*, *angular*, *nasal*, and *mental* arteries of mammalia.

"The *laryngeal* or *posterior palatine* artery is a little branch of the external carotid, which is sent off posteriorly opposite to the external maxillary artery. Its branches are exhausted upon the back part of the fauces, the muscles for moving the upper jaw, and posterior nares.

"The *lingual* or submaxillary artery (13) passes under the muscles which connect the os hyoides to the lower jaw, and close upon the back of the membrane of the lower part of the mouth, it sends a branch to the œsophagus and trachea, supplies the muscles of the os hyoides (*F*),

* Dr. Barkow has subsequently established the accuracy of this observation, having found this singular anastomosis of the occipital with the vertebral artery in all the birds which he has injected. Tiedemann is therefore inaccurate in saying that the vertebral artery has the same termination in birds as in man.

the tongue (*E*, *fig.* 170), the lower surface of the mouth, and furnishes the artery which enters the substance of the lower jaw.

"Just at the origin of the submaxillary artery there is another little branch of the carotid, which is lost upon the muscles of the os hyoides.

"The *internal maxillary* artery is, as usual, the continuation of the trunk of the external carotid; it runs forwards between the pterygoid muscle, and the lining of the mouth, upon the side of the long muscle for moving the upper jaw, and divides into two principal branches; one of them proceeds under the tendon of the long muscle to get upon the palate, where it forms two branches, of which one runs along the external side of the palate, between the membrane and the bone of the mandible to the extremity of the bill, where it becomes united to the same branch of the opposite side, as also to the middle artery of the palate. The other branch lies also superficially under the membrane which lines the mouth. It passes onwards to meet its corresponding vessel of the opposite side, with which it becomes actually incorporated, and by their union a single artery is generated, which runs along the middle line of the palate to the end of the mandible, where it unites with the lateral branches, as already mentioned. At the junction of the vessel of each side to form the middle palatine artery, two branches go off, which are lost upon the lining of the mouth, and the interior of the organ of smell.

"The other branch of the internal maxillary artery is reflected upwards towards the orbit, below which it divides and unites again, forming a triangle, through which the vein passes: at this place it produces a remarkable plexus of vessels, like the rete mirabile of the carotid artery of quadrupeds, which is increased by branches from the ophthalmic and the palatine arteries, and from which the back part of the organ of smell receives its supply of blood.

"The internal maxillary artery then runs directly backwards below the orbit, passes between the radiated or fan-shaped muscle which moves the upper jaw and the pterygoid process; and turning inwards round the basis of the cranium, becomes incorporated with the *internal carotid* artery just as it enters the bony canal which conducts it to the brain.*

"The *vertebral artery* (6), soon after it parts from the carotid, sends off a branch backwards, which passes over the neck of the scapula and is lost among the muscles on the posterior part of the shoulder, inosculating with the articular and other arteries about the joint: this branch might be called the *supra-scapular* (5). In the *duck* we have observed it, before it makes the turn over the scapula, to send an artery upwards along the muscles of the neck. The trunk of the vertebral artery proceeds obliquely upwards, and having entered the foramen in the transverse process of the second cervical vertebra, gives off a large branch downwards, which is distributed between the vertebræ, and to the spinal canal, in the manner of the intercostal arteries, with which it anastomoses upon arriving in the thorax. The remainder of the vertebral artery is continued upwards in the canal formed in the transverse processes of the cervical vertebræ, diminishing gradually in consequence of the branches it sends off between each vertebra to the spinal marrow and the muscles of the neck. Near the head the artery is found considerably reduced, and within the last foramen in the transverse processes terminates entirely by inosculation with the reflected occipital branch of the carotid, as before noticed.

"The extraordinary anastomosės and the plexuses which are to be observed in the arteries of the head in birds are not easily accounted for. It seems possible that they may be required in consequence of the great length of the neck in these animals, it being well known that frequent communication amongst the vessels, although it diminishes the impetus of the circulation, ensures a free and uninterrupted motion of the blood.

"After the common trunk of the carotid and vertebral is detached from the arteria innominata, this vessel may assume the name of the *subclavian* (14). While passing under the clavicle it sends off some important branches: the first might be called the *pectoral artery;* it proceeds upwards upon the internal surface of the pectoralis minimus muscle, which it supplies, and then dividing into two branches, one passes over the anterior edge of the clavicle, and under the pectoralis medius, between which and the sternum it runs, detaching its branches to the muscle; the other sends first along the under side of the clavicle a branch which is again subdivided and distributed to the outside of the shoulder-joint and to the deltoid muscle, in which it inosculates with the articular artery. The vessel then passes between the clavicle and the fork-shaped bone, and on a ligament which connects the head of the clavicle to that of the scapula, and disperses its branches upon the upper part of the shoulder-joint, forming anastomoses with the neighbouring arteries.

"The next branch of the subclavian is the *humeral artery* (15); it arises from the upper side of the vessel, and makes a slight curve to reach its situation on the inside of the arm in order to disperse its branches in the manner hereafter described.

"The *internal mammary* artery (24, *fig.* 171) is given off just as the subclavian leaves the chest. It divides into three branches; one ramifies upon the inner surface of the sternum, another upon the sternal ribs and the intercostal muscles, and the third runs along the anterior extremities of the vertebral ribs, supplying the intercostal muscles, &c.

"The chief peculiarity of the arteries of the superior extremities in birds consists in the great magnitude of the vessels which supply the pectoral muscles; these, instead of being inconsiderable branches of the axillary artery

* Barkow describes the internal maxillary artery as wanting in birds, and its place being supplied by branches of both the external and internal carotids and the facial artery, all of which sometimes unite to form the maxillary plexus of vessels, which is very conspicuous in the Goose and Duck.

are the continuations of the trunk of the subclavian, of which the humeral is only a branch.

"The *great pectoral* or *thoracic artery* passes out of the chest over the first rib and close to the sternum, and immediately divides into two branches. One of them (16) ramifies in the superior part of the pectoralis major, and the other (17) is exhausted in the lower part of the muscle, and sends off a branch analogous to the long thoracic artery of mammalia." Nos. 16 and 17 show the distribution of these arteries to the skin after perforating the *pectoralis* muscle.

"The *humeral artery*, while within the axilla, gives a small branch backwards to the muscles under the scapula, and upon reaching the inside of the arm produces an artery that soon divides into the articular and the profunda humeri. The *articular* artery passes round the head of the humerus, underneath the extensors; its branches penetrate the deltoid muscle, and anastomose with the other small arteries around the joint.

"The *profunda humeri*, as usual, turns under the extensor muscles to reach the back of the bone, at which place, in birds, it separates into two branches, of which one descends upon the inside, and the other upon the outside of the articulation of the humerus with the radius and ulna, and there inosculate with the recurrent branches of the arteries of the fore-arm.

"After the humeral artery has sent off the profunda, it descends along the inner edge of the biceps muscle, detaching some branches to the neighbouring parts: upon arriving at the fold of the wing, it divides into two branches; one of these is analogous to the *ulnar* artery, and the other fiom its position deserves to be called rather the *interosseous* than the radial artery.

"At the place where the humeral produces the two arteries of the fore-arm, a small branch is sent off, which is lost upon the fore-part of the joint, and in anastomoses with the recurrent of the ulna and profunda humeri.

"The *ulnar artery* is the principal division of the humeral; it proceeds superficially over the muscles which are analogous to the pronator, sends a large recurrent branch under the flexor ulnaris to the back of the joint, upon which it ramifies and forms anastomoses with the profunda humeri. The artery then proceeds along the inner edge of the ulnar muscles, to which it distributes branches. It is afterwards seen passing over the carpal bone of the ulnar side, and under the annular ligament, at which place it sends off some branches which spread upon the joint and inosculate with the similar ones of the interosseous artery. Very soon after the ulnar artery gets upon the metacarpus, it dips in between the bones, and re-appears upon the opposite side, lying under the roots of the quills, to each of which it sends an artery; it preserves this situation to the end of the metacarpal bones, where it passes between the style analogous to the little finger and the principal or fore-finger, and pursues its course along the edge of the latter, to the extremity of the wing, supplying each of the true quills with an artery, and sending at each joint of the finger a cross branch to communicate with the anastomosing branches on the opposite side.

"The *interosseous* artery detaches first a branch of some size to the membrane which is spread in the fold of the wing, upon which it forms several ramifications. (See *o*, *fig.* 171.) After this the artery dips down behind the pronator muscles to get into the space between the ulna and radius. It here gives a branch backwards to communicate with the others about the joint, and proceeds in the interosseous space as far as the carpal joint, during which course they become much diminished from giving off several branches which are distributed to the integuments and the quills placed upon the outside of the ulna. The remainder of the interosseous artery is expended in small branches upon the back of the carpal joint, the bastard quills, and along the radial edge of the metacarpus and bones of the fore-finger, where it forms communications with the cross branches of the ulnar artery already mentioned.

"From this description it will be perceived that no artery exists in birds strictly analogous to the radial; that there are no palmar arches; and that the size of the interosseous artery, and the course of the ulnar, along the outside of the metacarpus, are peculiarities which arise from the necessity of affording a large supply of blood to the quills during their growth.

"The *descending aorta* (19, *fig.* 170) makes a curve round the right auricle and right bronchus, in order to get upon the posterior surface of the heart, after which its course is close along the spine, in which situation it is bound down by cellular substance, and the strong membrane or aponeurosis, which covers the lungs on their anterior part. The first branches which this vessel appears to send off are *bronchial arteries;* they arise from the fore part of the aorta, just when it arrives upon the spine; and having entered the lungs, their ramifications accompany those of the pulmonary arteries. They appear also to send branches to the spine and the spaces between the ribs.

"The *intercostal arteries* do not take their origin from the aorta in numerous and regular branches as in mammalia, but consist originally of but few vessels, which are multiplied by anastomoses with each other, and with the arteries which come out of the spinal canal. An arterial plexus is thus formed round the heads of the ribs, from which a vessel is sent to each of the intercostal spaces. Many of these branches, besides supplying the intercostal muscles and ribs, are continued into the muscles upon the outside of the body and the integuments. The anastomosis of the intercostal arteries round the ribs is very similar to the plexus, which is produced by the great sympathetic nerve in the same situation.

"The aorta produces no branch which deserves the name of the *phrenic artery*, as birds do not possess that muscular septum of the body to which the artery of this name is distributed in other animals.

"The *cœliac artery* (20, *fig.* 170) is a very large single trunk, and arises from the fore part of the aorta, even higher than the zone of the gastric glands. It descends obliquely for a short way, and then gives off a branch which soon divides into two or three others that are spread upon the lower part of the œsophagus, and the side of the zone of the gastric glands, uniting with the other arteries of the œsophagus above, and extending downwards upon the posterior side of the ventricle, and anastomosing with the anterior gastric artery. The trunk of the cœliac now divides into two very large branches, which from their distribution we have chosen to call the posterior and the anterior gastric arteries.

"The posterior *gastric artery*, almost as soon as it is formed, detaches the *splenic* artery; and very soon after it furnishes from the posterior side of the vessel the right *hepatic artery*. This branch proceeds to the right lobe of the liver, which it enters on the side of the hepatic duct; after having divided into two or three minute arteries on its way to the liver, it supplies the hepatic duct with a branch which accompanies the duct to the intestine, and is there lost. The posterior gastric artery then runs down upon the back of the gizzard, and opposite to the origin of the first intestine it sends off an artery, which proceeds directly to one of the cœca (in the Fowl), upon which and the side of the next intestine it is expended, inosculating at the end of the cœcum with branches of the mesenteric artery, which are distributed to the adjoining portion of the small intestine. The posterior gastric then furnishes a large vessel which runs upon the gizzard, and divides into two chief branches, which penetrate the substance of the digastric muscle, in which they are lost.

"The next branch of the posterior gastric artery is the *pancreatic*. It runs between the two pancreatic glands, dispensing branches to each and to the duodenum. After this the trunk of the posterior gastric divides into two branches, which furnish twigs to the muscular parietes of the ventricle, and run along the margins of the upper and lower portions of the digastric muscle. Supplying them with numerous twigs, and anastomosing with the ramifications of the other gastric arteries.

"The *anterior gastric artery* descends to the angle formed by the bulbus glandulosus and the gizzard, and there sends off a small branch which spreads upon the zone of the gastric glands, and inosculates with the first ramifications of the cœliac, and immediately afterwards it detaches a large artery, which runs round the superior margin of the digastric muscle, which it furnishes with many twigs, and communicates freely with the corresponding branch of the posterior gastric artery.

"Three *small hepatic arteries* take their origin from this branch of the anterior gastric, just as it passes over the highest part of the margin of the gizzard; these vessels enter the fissure in the left lobe of the liver. The anterior gastric artery now proceeds along the fore part of the gizzard, sending one or two branches into the muscular substance, and near the tendon it terminates in two large vessels, one of which is distributed upon the left side of the digastric muscle, and the other passes a little over the tendon, and then divides into two arteries, which produce several branches that disappear in the substance of the gizzard, and between the digastric muscles and the parietes of the ventricle, anastomosing with the vessels of the posterior side.

"The *superior mesenteric artery* (21, *fig.* 170) takes its origin from the fore part of the aorta, a little below the cœliac, and proceeds for some way without detaching any branches; after which it experiences the same kind of division and subdivision that takes place in mammalia; and the numerous arteries which are thus ultimately produced are spent upon the small intestines. One of the first and largest branches of the superior mesenteric, however, is allotted to supply one of the cœca, and to establish a communication with the inferior mesenteric and gastric arteries. This branch, soon after it leaves the trunk of the superior mesenteric, divides into two. One descends upon the rectum, where it meets with the inferior mesenteric artery, with which it produces a very remarkable anastomosis, similar to the mesenteric arch in the human subject; this united artery supplies the rectum and origin of the cœca. The second portion of this branch of the superior mesenteric runs in the space between the last part of the small intestine and the cœcum of one side, sending numerous branches to each, and at the end of the cœcum communicates in a palpable manner with another branch of the superior mesenteric artery, which runs upon the adjoining part of the small intestine.

"A branch (22, *Arteria spermatica*) arises from the anterior part of the aorta, just below the lungs; it is designed for the nutrition of the organs of generation, and except in the season for propagation, it is so small as to be discovered with difficulty; but when the testicles become enlarged, it is considerably increased in size in the male bird, and much more so in the female, when the ovary and oviduct are developed for producing eggs. It nearly equals the superior mesenteric artery during the period of laying, in which state we shall describe it. It is a single artery, like the cœliac and mesenteric, proceeds at a right angle from the aorta, and soon sends off a branch, which goes into the kidney of the left side, to which it gives some twigs, and afterwards emerging from the kidney, it runs in the membrane of the oviduct, upon which it is distributed. After this branch is detached, the artery projects a little farther forwards into the cavity, and divides into two branches; one of these goes to the ovary, in which it ramifies, and furnishes an artery of some size to each of the cysts containing the ova. The other is distributed in numerous branches to the membrane and superior parts of the oviduct, and inosculates with the other arteries of the oviduct. It deserves to be remarked, that this and all the other arteries which are furnished to the oviduct have a tortuous or undulating course, in the same manner as the vessels of the uterus of the human subject.

"There are no regular *emulgent* arteries in birds; the kidneys deriving their blood from various sources, which will be pointed out as they occur

"The inferior extremity is supplied with two arteries, which have a separate origin from the aorta. One corresponds with the femoral artery, and the other deserves the name of ischiadic artery.

"The *femoral artery* (23, *fig*. 170, 171) is a small trunk, which takes its origin from the side of the aorta, opposite to the notch in the bones of the pelvis immediately under the last rib. This notch is formed into a round hole in the recent subject by a ligament which is extended from it to the rib; and it is through this hole that the femoral artery makes its exit from the pelvis; just before it passes out upon the thigh, it sends off a long branch (25), which runs backwards the whole length of the margin of the pelvis, dispensing arteries to the abdominal muscles on one side, and the obturator internus on the other. This branch also appears to supply one to the oviduct. The femoral artery, immediately after leaving the pelvis, separates into two branches; one goes upwards and outwards, ramifying amongst the muscles in that situation; the other turns downwards, and is distributed to the flexors of the limb and round the joint, and sends an artery to the edge of the vastus internus, which can be traced as far as the knee. The kidneys appear to derive some irregular inconsiderable branches from the femoral artery while it is within the pelvis.

"The *ischiadic artery* (26, *fig*. 166, 170) is the principal trunk of the lower extremities, exceeding very much in size the femoral. When it is produced by the aorta, it appears to be the continuation of that trunk; the remaining part of the aorta becomes so much and so suddenly diminished, and seems, as it were, to proceed as a branch from the back part of the vessel.

"The ischiadic artery, while in the pelvis, is concealed by the kidneys, in which situation it gives a branch from its lower side, which divides into three others that are distributed to the substance of the kidneys; one of these on the left side is continued out of the kidney to be lost upon the oviduct. The artery leaves the pelvis by the ischiadic foramen in company with the great nerve, while, within the foramen, it gives a branch obliquely downwards under the biceps to the muscles lying in the pelvis; and as it passes over the adductor it sends off another along the lower edge of that muscle, which is chiefly lost in the semi-membranosus. It then detaches several small branches to the muscles on the outer and fore part of the thigh, some of which anastomose round the joint with the branches of the femoral artery. Just as the ischiadic arrives in the ham, it furnishes a very large branch downwards, which divides into two; one goes under the gastrocnemius, to which and the deep-seated flexors its branches are distributed as far as the heel; the other is analogous to the *peroneal artery;* it goes to the outside of the leg, supplies the peroneal muscles posteriorly, and passes along the outer edge of the flexors of the toes to the heel, above which, and behind the flexor tendon, it divides, running on each side of the heel, and forming several articular arteries around the joint, and communicating with the other branch, and with the anterior tibial, and the metatarsal branch of the plantar artery.

"The *articular arteries* go off next from the artery in the ham; the two principal ones are deep-seated. One proceeds under the vastus internus to the external part of the joint; the other is large, and situated upon the inside. It forms two vessels: one is the true articular artery, and spreads upon the ligaments of the joint; the other is distributed in the substance of the flexor of the heel, which is placed upon the inside and fore part of the leg, and comes out upon the edge of this muscle to be lost in the integuments.

"The *posterior tibial artery* (28, *fig*. 171) is extremely small; it only supplies muscular branches to the internal head of the gastrocnemius, and some of the flexors of the toes; it is lost on the inside of the heel in anastomoses with the peroneal artery, and other small superficial branches.

"The trunk of the artery of the leg now gets upon the posterior surface of the tibia, and sends off, through the deficiency left between the tibia and fibula at the superior part, a branch which is distributed to all the muscles upon the fore part of the leg. The artery then creeps along the back of the bones for some way, and passing between them above, where the fibula is anchylosed with the tibia, it reappears on the anterior part of the leg in the situation of the *anterior tibial artery;* at this place it detaches some very small branches, which frequently divide and unite again, to produce a most singular reticulation or plexus of vessels, which closely adheres to the trunk of the artery, and is continued with it as far as the articulation of the tibia with the metatarsal bone, where it disappears without seeming to answer any useful design. This plexus resembles in appearance exactly the division of the arteries of the extremities, which has been described by Mr. Carlisle in the tardigrade quadrupeds, but differs from it in this circumstance, that the trunk of the artery is preserved behind it, without suffering any material diminution of its size.

"The anterior tibial artery furnishes no branch of any importance during the time it is proceeding along the fore part of the leg. It passes under the strong ligament which binds down the tendons of the anterior muscles of the leg, and over the fore part of the joint on the inside of the tendon of the tibialis anticus, at which places it distributes some branches which inosculate with the other arteries round the joint; it then pursues its course in the groove along the anterior surface of the metatarsal bone, and covered by the tendon of the flexor digitorum. On coming near the foot it sends off an artery, which divides, behind the joint of the internal toe, into two branches;

one goes between the internal and middle toes, ramifies upon both their joints, and unites with the artery in the sole of the foot; the other is distributed between the internal toe, and the pollex or toe which occupies the place of the great toe; the main artery now passes to the sole of the foot through a hole in the metatarsal bone, left for the purpose, when the original parts of this bone were united by ossification. In this situation the artery might receive the name of the *plantar*. It has scarcely passed through the bone, when it divides into six branches; three of these are distributed to the tendons and ligaments, &c. on the outside of the foot and the back of the metatarsus, anastomosing with the descending branches of the peroneal artery; the fourth branch supplies the pollex, and also sends a branch from the metatarsus. The remaining branches are designed for the three principal toes; one dips in between the internal and middle toe, unites with the anterior branch of the metatarsal artery, and is distributed to the sides of these toes as far as their extremity. The other divides, between the external and middle toe, into two branches, which run upon the opposite side of each of these toes to the end.

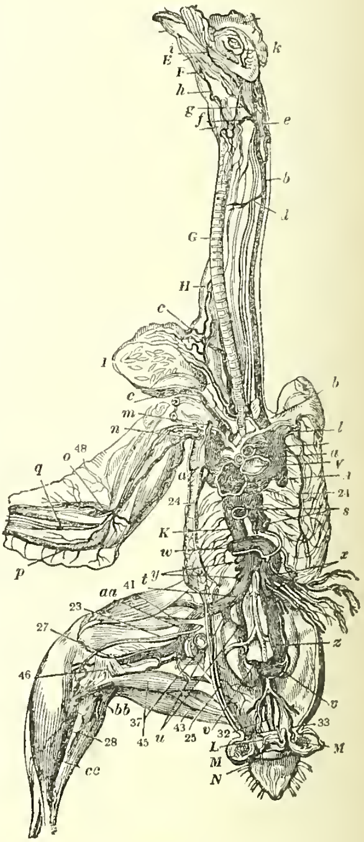
" When the feet are webbed, the digital arteries send off numerous branches, which, ramifying in the membrane between the toes, establish a communication with each other. The present description has been taken from birds which possess three principal toes, and the back toe or pollex; but no material difference can be expected in those with a greater number of toes.

" After the trunk of the aorta has detached the ischiadic arteries, it is continued along the spine as the *arteria sacra media* (29, *fig.* 170), sending off small branches analogous to the *lumbar* arteries, one of which ascends upon the rectum, supplies the place of the *inferior mesenteric* (30, *fig.* 170), and unites with the superior mesenteric as already mentioned. The aorta separates above the coccygeal vertebræ into three branches; two of these, (the *hypogastric arteries*, 31, *fig.* 170,) proceed laterally, and are distributed to the neighbouring parts, and to the kidneys and oviduct; the third branch (the *coccygeal artery*, 32, *fig.* 170) descends to the very point of the tail, upon the muscles and quills of which its branches are exhausted.

" The arterial system of birds, besides the distinguishing characters above-mentioned, differs from that of mammals chiefly in the frequent anastomoses, which exist more especially amongst the arteries of the head and the viscera. Similar communications occur between the veins, which are even in some instances more singular and unaccountable, as will be perceived by the following description, which has been taken principally from the Goose, Duck, and Common Fowl."

Besides the remarkable arterial plexuses mentioned in the general description, as the orbital, the temporal, the spermatic plexuses, &c., that which Barkow has described under the name of the plexus of the organ of incubation (*Brüt-organe*) deservese special notice. It is represented at 17, 18, *fig.* 170, and is composed of branches coming from the posterior thoracic, abdominal, cutaneous, and ischiadic arteries, which ramify beneath the integument of the abdomen, and form, by their unions, a rich network of vessels which becomes truly extraordinary in the time of hatching. At this period many birds pluck off the feathers from the seat of incubation, probably thereto impelled by the great degree of heat caused by the influx of blood into the incubating plexus.

Fig. 171.



Veins of a Fowl.

" *Veins.*—The venous system returns the blood to the heart by means of three trunks; two of these, for the convenience of description, we shall call the subclavian veins (*a a*, *fig.* 166), although they do not correspond in every respect with the veins of this name in mammalia; the other trunk is analogous to the inferior vena cava.

" The *subclavian vein* (*a*, *fig.* 171) is composed of the jugular and vertebral, and the veins which belong to the superior extremity or wing.

" The *vertebral vein* is lodged in the same canal with the vertebral artery; it anastomoses between the vertebræ with the veins upon the sheath of the medulla spinalis, which are the continuation of the sinuses of the brain; in conjunction with these, therefore, the vertebral vein may be considered as answering the purpose of the internal jugular of mammalia. It appears also to form at the basis of the cranium a free communication with the jugular vein, and to receive, by occasional branches, blood from the muscles of the neck.

"The *jugular vein* (*b*) is a single trunk in birds, and does not admit of the distinction into external and internal; it proceeds superficially along the side of the neck in company with the par vagum nerve. The vein of the right side exceeds the other in size; it is often twice as large. The jugular vein receives several lateral branches from the muscles and integuments of the neck (*d*), the œsophagus, &c. (the veins from the crop joining the jugular are shewn at *c*): one of these near the head is much longer than the rest (*e*); it lies deep amongst the muscles, and appears to communicate with the vertebral vein. There is a branch of the jugular which goes to the superior larynx amongst the muscles of the tongue and of the os hyoides, and another for the muscles within the jaws and the integuments in the back of the mouth; these might be called the *lingual, thyroid,* and *submaxillary* veins (*g h i*).

"The jugular veins form a most remarkable communication with each other immediately below the cranium, by means of a cross branch, generally of an equal size with the trunks themselves. From each side of the arch thus formed there issues a large vessel, which is made up of the veins of the external part of the head; one of these passes round the articular bone, and apparently penetrates the joint of that bone with the lower jaw; it appears in several branches upon the side of the cheek, and spreading from the ear in the manner of the portio dura nerve of the human subject, and contributes to form a plexus of veins below the posterior part of the orbit (*k*), similar to the arterial plexus already described in that situation. The principal branch of the veins of the head passes obliquely round the interarticular (or pterygoid) bone, and below the orbit divides into several large vessels, one of which belongs to the back part of the palate; another ascends on the orbit, and unites with the ophthalmic vein; and a third is distributed to the interior of the organ of smell, the palate, and the external parts of the upper and lower jaws. These branches produce plexuses along the base of the orbit and the external edge of the palate, which correspond to those of the arteries before described.

"In all the subjects we dissected for the veins, we failed to discover any direct communication between the jugular vein and the sinuses of the brain; and in every instance the external veins of the head appeared to be sufficiently large of themselves to produce the trunk of the jugular. It may, therefore, be presumed that if any branch analogous to the internal jugular vein passes through the posterior foramen lacerum, it is very inconsiderable, and incapable of transmitting the blood of the brain.

"The *sinuses of the brain* seem to discharge their contents principally into some veins which lie in the membrane forming the sheath of the spinal canal, and these appear to dispose of their blood gradually, as they descend in the neck by means of lateral communication with the vertebral veins. The sinuses, which immediately open into the spinal veins, are situated upon the back of the cerebellum, and produce, by anastomoses with each other, with the superior longitudinal sinus, and with others along the side of the brain, an union of vessels of a diamond shape.

"The sinuses of the brain in birds generally are irregular in their form, and consist of flattened canals; and not only the sinuses on the back of the cerebellum, but the spinal veins appear so like extravasation, that accurate and repeated observations are necessary to discover them to be real vessels.

"The principal sinuses, besides those upon the cerebellum, are the superior longitudinal, and one which runs along the lower edge of each hemisphere of the cerebrum; there appears to be also one upon the side of the cerebellum, corresponding to the lateral sinus. All these sinuses communicate with each other on the back of the cerebellum as already mentioned. The superior longitudinal sinus is continued at its anterior part under the frontal and nasal bones, and anastomoses with the ophthalmic and nasal veins. There are other sinuses in the several duplicatures of the dura mater, which are too small to be easily traced or to deserve much regard.

"The *veins of the wings*, or superior extremity, have a less curious distribution than those of the head. The branches which are derived from the parts within the chest, the muscles about the scapula, and the pectoral muscles, accompany the arteries of the same parts so regularly that their course does not require description.

"The *axillary vein* (*l*) lies considerably lower in the axilla than the artery, but still continues to receive corresponding branches; (*m* indicates the great pectoral vein). The trunk of the vein descends in the course of the humeral artery, but more superficially; in this situation it may be called *basilic*, or more properly the *humeral*, vein (*n*). There is no vein in birds which deserves the name of the *cephalic*; there are branches of the humeral vein, accompanying the articular and profunda arteries, and at the middle of the humerus a large branch of the vein enters the bone; there are also two very small branches which lie in close contact with the humeral artery, which they accompany nearly its whole length.

"The principal vein of the wing divides into two, opposite to the joint of the humerus with the fore-arm. One of these branches (*o*) belongs to the sides of the radius; it receives blood from the muscles and skin on the upper part of the fore-arm, but its chief vessels lie between the integuments of the fold of the wing. The other branch of the humeral vein (*p*) crosses the fore-arm, just below the articulation in company with the nerve, and running along the inferior edge of the ulna, receives a branch from between the basis of each quill, is continued along the ligament which sustains the rest of the quills to the extremity of the wing, receiving many veins of the joints from the opposite side of the fingers. Besides these large superficial veins of the fore-arm, there appears to be one, and sometimes two, small accompanying veins to the ulnar and interosseous arteries (*q*).

"The *inferior vena cava* (K), before it enters the auricle (A), receives as usual the *hepatic veins* (*s*); these are numerous, and open into the cava as it passes behind the liver, or more frequently within the substance of that viscus in the back part. We have reckoned in the Cock two large and two small hepatic veins from the right lobe, and one large branch from the left lobe, besides six minute veins, which came indifferently from both lobes.

"The trunk of the *vena cava* is very short in the abdomen; it separates into two great branches analogous to the primary *iliac veins* (*t*), opposite to the renal capsules; these turn to each side, and experience a very singular distribution. On coming near the edge of the pelvis each of these two veins forms two branches; one of which collects the blood of the lower extremity, as hereafter described; the other passes straight downwards imbedded in the substance of the kidney, and admits the several emulgent veins, which are very large, and are seen to pass for some way obliquely in the kidney before their termination. Sometimes the *emulgent veins* are double, as in the figure, (*u*). The descending branch of the iliac also receives the ovarian veins, and when arrived at the lower end of the kidney, divides into three branches; one transmits the blood of the muscles of the tail and parts adjacent; another accompanies the ureter to the side of the rectum, and is distributed about the anus and parts of generation, answering to the *hæmorrhoidal* veins; the third (*v*, *v*) passes inwards to the middle line between the kidneys, and there unites with the corresponding branch of the opposite side.* The vessel which is in this manner produced (*z*) receives all the blood of the rectum from the anus to the origin of the cœca, anastomosing below with the branches of the hæmorrhoidal veins; and at the upper part of the rectum, it becomes continuous with the trunk of the veins of the small intestines (*x*), forming the most remarkable anastomosis in the body, both on account of its consequences and the size of the vessels by which it is effected. By means of this communication, the blood of the viscera and the external parts of the body flows almost indifferently into the vena cava and vena portæ (*w*); for the anastomosing vessels are sufficiently large to admit the ready passage of a considerable column of blood in proportion to the whole mass which circulates in the body of the bird; for instance, in the Goose the communicating veins of the pelvis are equal in size to a goose-quill, and in the Ostrich and Cassowary they are as thick as a finger. The advantage which appears to result from this remarkable union of vessels, is the prevention of congestion, or the overloading either the heart or liver with blood, as the one organ has the power of relieving the other. It would seem from this, as well as several other provisions of the same kind, that the circulation would be more liable to obstruction in birds than other animals.* It is difficult to say, however, to what cause such an effect ought to be ascribed. Is it from the compression sustained by the heart and other viscera, by means of the air-cells during respiration? or, is the mode of progression by flight capable of impeding the motion of the blood?

"The anastomosis of the pelvic veins, in being the means of conveying common venous blood into the liver, goes to prove that the blood of the vena portæ does not require any peculiar preparation by circulation in the spleen or other viscera, which has been conceived as necessary by some physiologists to fit it for the secretion of bile.

"The *vena portæ* (*w*) belongs almost exclusively to the right or principal lobe of the liver. It is formed by three branches. The *splenic vein* is the smallest, and is added to the vena portæ, just as it penetrates the liver on the side of the hepatic duct. The next is made of two branches; of which one returns the blood of the posterior gastric artery, and therefore may be called the *posterior gastric vein*; and the other is furnished by the pancreas and duodenum, and therefore is the *pancreatic* vein. The third and largest branch of the vena portæ is the *mesenteric vein* (*x*), which not only collects the blood from all the small intestines, but likewise receives the *inferior mesenteric* (*z*), or vein of the rectum, which forms the communication that has been described with the pelvic veins.

"The *veins of the left lobe of the liver* are furnished in the *goose* by those which accompany the anterior gastric artery, and some branches from the head of the duodenum.

"The *anterior gastric veins* produce two small trunks, which enter at the two extremities of the fissure, in the concave surface of the left lobe of the liver, as it lies upon the edge of the gizzard; the veins from the head of the duodenum furnish a small vessel which passes backwards to penetrate the posterior part of the fissure in the left lobe.

"In the *cock* the veins that the left lobe of the liver derives from the anterior gastric, are more numerous than in the *goose*.

"The veins of the zone of gastric glands, and of the lower portion of the œsophagus, do not

* It is these branches which Professor Jacobson supposes to carry venous blood *into* the kidneys, for the purpose of supplying material for the urinary secretion.

* Besides their anastomoses the principal visceral veins are remarkable for their large size in the Diving Birds. Cuvier (*Leçons d'Anat. Comp.* iv. p. 274) has especially noticed the dilatation of the inferior cava of the Grebes (*Colymbus*), which reservoir he compares with that formed by the hepatic veins in the Seal.

contribute to the secretory vessels of the liver, but proceed to the superior part of that viscus, to terminate in the vena cava, as does also the umbilical vein.

"The vein which returns the blood of the inferior extremities is divided in the pelvis into two branches, which correspond with the femoral and ischiadic arteries; the one passes through the ischiadic foramen, and the other through the hole upon the anterior margin of the pelvis; but the proportion they bear to each other in magnitude is the very reverse of what occurs in the arteries; for the anterior vein is the principal one, whilst the other is not a very considerable vessel, and receives its supply of blood from the muscles at the posterior part of the joint.

"The *femoral vein* (*a a*), immediately without the pelvis, gives branches on both sides, which receive the blood of the extensor and adductor muscles at their superior part: the trunk passes obliquely under the accessory muscle of the flexor digitorum, and over the os femoris, where it lies superficially; it then winds under the adductor muscles, and gets into the ham (*b b*), where it receives many muscular branches, and comes into company with the artery and nerve. It here divides into the *tibial* (*c c*) and *peroneal* veins. The first is joined by some branches from the surface of the joint answering to the articular arteries; it also receives the *anterior* tibial vein which accompanies the artery of the same name. The tibial vein proceeds down the leg along with the artery on the inside of the deep-seated flexors of the heel: it turns over the fore part of the articulation of the tibia with the metatarsal bone, in order to get upon the inner side of the metatarsus; above the origin of the pollex, it receives a communicating branch from the peroneal vein, and immediately after two branches from the toes: one of them comes from the inside of the internal toe; the other arises from the inside of the external and middle toes, unites at the root of the toes in the sole of the foot, and is joined by a branch from the pollex, before its termination in the internal vein of the metatarsus.

"The *peroneal vein* derives its principal branches along with those of the peroneal artery, from the muscles on the outside of the leg. The trunk of the vein comes out from the peroneal muscles, and passes superficially over the joint at the heel, and along the outside of the metatarsus; near the pollex, or great toe, it sends a branch round the back of the leg, to communicate with the tibial vein; after which it is continued upon the outside of the external toe to the extremity, receiving anastomosing branches from the tibial vein.

"Where the veins run superficially upon the upper and lower extremities, they seem to supply the place of the branches of the *cephalic, basilic*, and the two *saphenæ;* but the analogy is lost upon the upper arm and thigh, these branches forming deep-seated trunks; this constitutes the greatest peculiarity in the distribution of the veins in the extremities of birds."

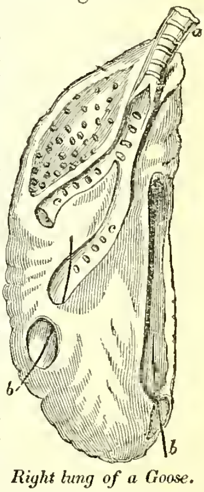
Respiratory organs.—In the course of this article we have frequently had occasion to allude to the extent and activity of the respiratory function in the Class of Birds;* nevertheless the organs subservient to this function manifest more of the peculiarities of the Reptilian than of the Mammalian type of formation.

The lungs are confined, as in the Tortoise, to the back part of the thoracic-abdominal cavity, being firmly attached to the ribs and their interspaces; and, as in the Serpent, they communicate with large membranous cells which extend into the abdomen and serve as reservoirs of air.

In those aquatic Birds, which are deprived of the power of flight, as the Penguins, the air receptacles are confined to the abdomen; but in the rest of the class they extend along the sides of the neck, and, escaping at the chest and pelvis, accompany the muscles of the extremities. They also penetrate the medullary cavities and diploë of the bones, extending in different species through different proportions of the osseous system, until in some birds, as the Horn-bill, every bone of the skeleton is permeated by air.

There is, indeed, no class of Animals which are so thoroughly penetrated by the medium in which they live and move as that of Birds.

Fig. 172.



Right lung of a Goose.

The *lungs* (*w*, *fig.* 172) are two in number, of a lengthened, flattened, oval shape, extending along each side of the spine from the second dorsal vertebra to the kidneys, and laterally to the junction of the vertebral with the sternal ribs. They are not suspended freely as in Mammalia, but are confined to the back part of the chest by cellular membrane, and the pleura is reflected over the sternal surface only, to which the strong aponeurosis of the diaphragmatic muscles is attached. They are consequently smooth and even on the anterior surface, but posteriorly are accurately moulded to the inequalities of the ribs and intercostal spaces.

The lungs in general are of a bright red colour, and of a loose spongy texture. The bronchi (*u*, *fig.* 163; *a*, *fig.* 172) penetrate their mesial and anterior surfaces about one-third from the upper extremities; they divide into four, five, or six branches, which diverge as they run along the anterior surface; some incomplete cartilaginous rings are found through their entire extent.

The orifices of the air-cells of the lungs (*c c*, *fig.* 172) open upon the posterior parietes of the bronchial tubes, while the extremities of these tubes terminate by wide openings (*b b*, *fig.* 172) in the thoracic and abdominal air-receptacles. These orifices are oblique, and

* According to Lavoisier, two Sparrows consume as much oxygen in a given time as one Guinea-pig.

are partially covered by a slight projection of membrane.

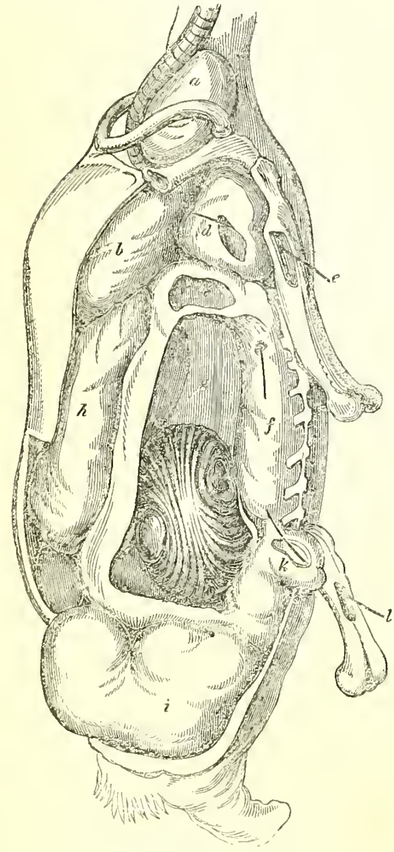
The pulmonary artery divides, almost immediately after its origin, into two branches, one to each lung; the ramifications of each artery form plexuses upon the air-cells, and freely anastomose with the pulmonary veins; these leave the lung by a single trunk, and the two pulmonary veins unite into one before terminating in the left auricle.

The thoracic-abdominal cavity is subdivided and intersected by a number of membranes; the greater part of the cells thus formed are filled with air. The texture of their parietes possesses considerable firmness in the larger birds, as the Ostrich and Cassowary, in which they were described by the French Academicians as so many distinct bags.

The innermost layer of the air-receptacles can be separated from the outer layer, and is a continuation of the lining membrane of the bronchial tube; the outer layer is a serous membrane, and appears to form the cells by a series of reflections of what may be regarded as the pleura or peritoneum.

These large membranous receptacles into which the extremities of the bronchial tubes open are disposed with sufficient general regularity to admit of a definite description and nomenclature.

Fig. 173.



Air-receptacles of a Swan.

The first or *inter-clavicular* air-cell (*a*, *fig.* 173) extends from the anterior part of each lung, forwards to the interspace of the furculum, anterior to which it dilates in the Gannet and many other birds into a large globular receptacle. In the Vultures it is divided into two lateral receptacles, between which the large crop is situated. A thin fan-shaped muscle is extended from the anterior edge of the furculum, over the interclavicular air-cell in these and some other birds

The *anterior thoracic* cell (*b*) contains the lower larynx and bronchi, and the great vessels with their primary branches to the head and wings. It is traversed by numerous membranous septa, which connect the different vessels together, and maintain them in their situations. The air passes into the posterior part of this receptacle by two openings at the anterior part of the lungs. The deep-seated air-cells of the neck are continued from it anteriorly.

The *lateral thoracic* cells (*d*) are continued on each side from a foramen on the inner edge of the lung, situated just opposite the base of the heart; they are covered by the anterior thoracic air-cell, and from them the air passes into the *axillary* and *subscapular* cells, into those of the wing, and into the humerus (*e*). They also communicate with the *cellula cordis posterior* (*c*), behind the heart and bronchi, which cell is often subdivided into several small ones.

The *cellulæ hepaticæ* are of much larger size; they are two in number, of a pyramidal figure, with their bases applied to the lateral thoracic cells, and their apices reaching to the pelvis: they cover the lower portions of the lungs and the lobes of the liver; they receive air from several foramina situated near and at the external edge of the lungs.

The *cellulæ abdominales* commence beneath the cellulæ hepaticæ at the inferior extremity of the lungs, where the longest branches of the bronchiæ open freely into them. (A bristle is passed through one of these openings in the figure.) They are distinguished into *right* (*f*) and *left* (*h*); the former is generally the largest receptacle in the body; it extends from the last ribs to the anus, and covers the greater part of the small intestines, the supra-renal gland, and kidney of the same side. The left abdominal cell (*h*) contains the intestines of its own side, and is attached to the gizzard. In some large Birds, as the Gannet, it is separated from the right receptacle by a mediastinal membrane (*g*) which is continued from the gizzard to the anus.

Both the abdominal receptacles transmit air to the *pelvic* cells (*i*, *k*) of their respective sides, and to several small and extremely delicate cells between and behind the coils of intestine. One of these is continued round the fold of the duodenum and pancreas to the gizzard, and has been termed the *duodenal cell*.

From the inguinal cell are continued the intermuscular *glutæal* and *femoral* cells, which surround the head of the femur, and communicate with that bone by an aperture (*l*) situated immediately anterior to the great trochanter, except in those Birds in which the femur retains its medulla.

The *cervical* air-cells are continued from the large clavicular cell, and form in the *Argala* a singular appendage or pouch, contained in a loose fold of integument, which the bird can inflate at pleasure.

In the Pelecan and Gannet extensive air-cells are situated beneath almost the whole of the integument of the body, which is united to the subjacent muscles only here and there by the septa of the cells and the vessels and nerves which are supported by the septa in their passage to the skin. The large pectoral muscles and those of the thigh present a singular appearance, being, as it were, cleanly dissected on every side, having the air-cavities above and beneath them. The axillary vessels and nerves are also seen passing bare and unsupported by any surrounding substance through these cavities. Numerous strips of *panniculus carnosus* pass from various parts of the surface of the muscles to be firmly attached to the skin; a beautiful fan-shaped muscle is spread over the inter-clavicular or furcular air-cell. The use of these muscles appears to be to produce a rapid collapse of the superficial air-cells, and an expulsion of the air, when the bird is about to descend, in order to increase its specific gravity, and enable it to dart with rapidity upon a living prey.

The air-receptacles of the thoracic-abdominal cavity present varieties in their relative sizes and modes of attachment in different birds. In the *Raptores* they are principally attached posteriorly to the ribs, the diaphragmatic aponeurosis covering the lungs, and to the kidneys; while in the Grallatores they have anterior attachments to the intestines in many places.

The singular extension of the respiratory into the osseous system was discovered almost simultaneously by Hunter and Camper, and ably investigated by them through the whole class of Birds. The air-cells and lungs can be inflated from the bones, and Mr. Hunter injected the medullary cavities of the bones from the trachea. It is stated that if the femur into which the air is admitted be broken, the bird shall not be able to raise itself in flight. It is certain that if the trachea be tied, and an opening be made into the humerus, the bird will respire by that opening for a short period, and may be killed by inhaling noxious gases through it.* If an air-bone of a living bird, similarly perforated, be held in water, bubbles will rise from it, and a motion of the contained air will be exhibited, synchronous with the motions of inspiration and expiration.

The proportion in which the skeleton is permeated by air varies in different Birds. In the Penguin *(Aptenodytes)*, which we have examined for this purpose, air is not admitted into any of the bones. Its chief progression being in water, the specific levity of the body gained by the substitution of air for marrow would be rather a detriment than an advantage. The condition of the osseous system, therefore, which all birds present at the early periods of existence, is here retained through life.

In the large Struthious Birds, which are remarkable for the rapidity of their course, the thigh-bones and bones of the pelvis, the vertebral column, ribs, sternum and scapular arch, the cranium and lower jaw, have all air admitted into their cavities or cancellous structure. The humeri and other bones of the wings, the tibiæ and distal bones of the legs, retain their marrow.

With the exception of the Woodcock, all Birds of Flight have air admitted to the humerus.

The Pigeon tribe, with the exception of the Crown Pigeon, have no air in the femur, which retains its marrow. In the Owls also the femur is filled with marrow; but in the Diurnal Birds of Prey, as in almost all other Birds of Flight, the femur is filled with air.

In the Pelecan and Gannet the air enters all the bones with the exception of the phalanges of the toes. In the Hornbill even these are permeated by air.

Mr. Hunter* has given the following characters as distinguishing the bones which receive air. They may be known—"first, by their less specific gravity; secondly, by their retaining little or no oil, and, consequently, being more easily cleaned, and when cleaned, appearing much whiter than common bones: thirdly, by having no marrow, or even any bloody pulpy substance in their cells; fourthly, by not being in general so hard and firm as other bones; and, fifthly, by the passage that allows the air to enter the bones, which can easily be perceived."

We have reserved for this section the description of the foramina by which the air penetrates the different bones. These openings may be readily distinguished in the recent bone, since they are not filled up by blood-vessels or nerves, but have their external edges rounded off.

In the dorsal vertebræ the air-orifices are small, numerous, and irregular; situated along the sides of the bodies, and the roots of the spinous processes, the air passes into them directly from the lungs. In the two or three lower cervical vertebræ the air-holes are in the same situation, but receive the air from the lower cervical or clavicular air-cells: in the remainder of these vertebræ the air-holes are situated within the canal lodging the vertebral artery, and communicate with the lateral air-cells of the neck.

* "I cut the wing through the os humeri in a Fowl, and tying up the trachea found that the air passed to and from the lungs by the canal in this bone. The same experiment was made with the os femoris of a young Hawk, and was attended with a similar result. But the passage of air through the divided parts, in both these experiments, especially in the last, was attended with more difficulty than in the former one; it was indeed so great, as to render it impossible for the animal to live longer than evidently to prove that it breathed through the cut bone."—*Hunter's Animal Œconomy*, p. 94.

* Animal Œconomy, p. 91.

The air-holes of the vertebral ribs are situated at the internal surface of their vertebral extremities, and appear like those of the contiguous vertebræ to have an immediate communication with the lungs. The sternal ribs, or ossified costal cartilages, have also internal cavities which receive air from the lateral thoracic cells by means of orifices placed at their sternal extremities.

The orifices by which air is admitted to the sternum are exceedingly numerous, but are principally situated along the mesial line of the internal surface, opposite the origin of the keel, forming a reticulation at that part; the largest foramen is near the anterior part of the bone; some smaller ones occur at the costal margins. All these orifices communicate with the thoracic air-receptacles.

The scapula is perforated by several holes at the articular extremity, which admit air into its cancellous structure from the axillary cell.

The coracoid has small air-holes at both extremities; the largest is situated on its inner surface, where it is connected with the clavicle or furculum.

The furculum receives air principally by a small hole in the inner side of each of its scapular extremities, which communicates with the clavicular air-cell.

The air-hole of the humerus is of large size, and situated at the back part of the head of the bone, below the curved inferior process. It communicates with the axillary air-cell, and transmits the air to the cavity of the bone by several cribriform foramina.

The air-holes of the pelvic bones are situated irregularly on the inner surface upon which the kidneys rest, and must therefore receive air from continuations of the abdominal receptacles around the kidneys.

The air-hole, or rather air-depression of the femur, is situated at the anterior part of the base of the trochanter; it receives air from the glutæal cell, and transmits it by several small foramina into the interior of the bone. In the Ostrich, the air-holes are situated at the posterior part of the bone at both of its extremities.

The cavities of the long bones into which air is thus admitted are proportionally larger than in the corresponding bones of Mammalia, and are characterized by small transverse osseous columns which cross in different directions from side to side, and are more numerous near the extremities of the bone; they abut against and strengthen, like cross-beams, the parietes of the bone.

We have sometimes succeeded in filling with fine size-injection the minute arteries which ramify on the membrane lining these cavities, but the vascularity of this membrane is by no means very remarkable.

The lower jaw receives its air by means of an orifice situated upon each ramus behind the tympano-maxillary articulation. Mr. Hunter was in doubt as to whether the lower jaw derived its supply of air from the Eustachian tube or the trachea where it passes along the neck.* In a Pelecan which we dissected for the purpose we found it to be supplied by an air-cell which surrounded the joint, and was continuous with the upper cervical air-cells. The bones of the cranium and upper jaw have communications with the Eustachian tube, but not with the nasal passages, which are every where lined with an impervious pituitary membrane.

Various explanations have been given of the final intention of the condition of the respiratory system above described.

The extension of this system by means of continuous air-receptacles throughout the body is subservient to the function of respiration, not only by a change in the blood of the pulmonary circulation effected by the air of the cells on its re-passage through the bronchial tubes, but also, and more especially, by the change which the blood undergoes in the capillaries of the systemic circulation, which are in contact with the air-receptacles. The free outlet to the air by the bronchial tubes does not, therefore, afford an argument against the use of the air-cells as subsidiary respiratory organs, but rather supports that opinion, since the inlet of atmospheric oxygenated air to be diffused over the body must be equally free.

A second use may be ascribed to the air-cells as aiding mechanically the actions of respiration in Birds. During the act of inspiration the sternum is depressed, the angle between the vertebral and sternal ribs made less acute, and the thoracic cavity proportionally enlarged; the air then rushes into the lungs and into the thoracic receptacles, while those of the abdomen become flaccid: when the sternum is raised or approximated towards the spine, part of the air is expelled from the lungs and thoracic cells by the trachea, and part driven into the abdominal receptacles, which are thus alternately enlarged and diminished with those of the thorax. Hence the lungs, notwithstanding their fixed condition, are subject to due compression through the medium of the contiguous air-receptacles, and are affected equally and regularly by every motion of the sternum and ribs.

A third use, and perhaps the one which is most closely related to the peculiar exigences of the bird, is that of rendering the whole body specifically lighter; this must necessarily follow from the dessication of the marrow and other fluids in those spaces which are occupied by the air-cells, and by the rarefaction of the contained air from the heat of the body.

Agreeably to this view of the function of the air-cells, it is found that the quantity of air admitted into the system is in proportion to the rapidity and continuance of the bird's motion; and that the air is especially distributed to those members which are most employed in locomotion; thus the air is admitted into the wing-bones of the Owl, but not into the femur; while in the Ostrich the air penetrates the femur, but not the humerus or other bones of the wing.

A fourth use of the air-receptacles, which has not hitherto been suspected, relates to the

* Loc. cit. p. 93.

mechanical assistance which they afford to the muscles of the wings. This was first suggested to us by observing that an inflation of the air-cells in a Gigantic Crane (*Ciconia Argala*) was followed by an extension of the wings, as the air found its way along the brachial and anti-brachial cells.* In large birds, therefore, which, like the Argala, hover with a sailing motion for a long-continued period in the upper regions of the air, the muscular exertion of keeping the wings outstretched will be lessened by the tendency of the distended air-cells to maintain that condition. It is not meant to advance this as any other than a secondary and probably partial use of the air-cells. In the same light may be regarded the use assigned to them by Hunter, of contributing to sustain the song of Birds, and to impart to it tone and strength. It is no argument against this function that the air-cells exist in birds which are not provided with the mechanism necessary to produce tuneful notes; since it was not pretended by Hunter that this was the exclusive and only office of the air-cells. The latest writer on this subject has indeed proposed this suggestion of Mr. Hunter as a novel idea.†

Air-passages.—The air-passages in birds commence by a simple *superior larynx*, from which a long *trachea* extends to the anterior aperture of the thorax, where it divides into the two *bronchi*, one to each lung. At the place of its division there exists, in most birds, a complicated mechanism of bones and cartilages moved by appropriate muscles, and constituting the true organ of voice: this part is termed the *inferior larynx*.

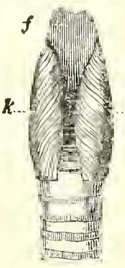
The tendency to ossification, which is exemplified in the bony condition of the costal cartilages and tendons of the muscles, is again manifested in the framework of the larynx and the rings of the trachea, which, instead of being cartilaginous, as in Reptiles and Mammals, are in most birds of a bony texture.

The *superior larynx* (*fig.* 151, 174, 175,) is situated behind the root of the tongue, and rests upon the uro-hyal element of the os hyoides, to which it is attached by dense cellular texture.

It is composed of several bony and cartilaginous pieces, varying in number from four to ten. The largest of these pieces constitutes the anterior part of the larynx. It is of an oval or triangular form, according as its superior termination is more or less pointed: it is regarded by Cuvier as analogous to the anterior part of the cricoid cartilage, (Leçons d'Anat. Comp. iv. p. 489,) but by Carus it is considered as representing the thyroid cartilage (*f*, *fig.* 151). The cricoid cartilage in birds consists of the three osseous pieces, which are situated at the posterior and inferior part of the upper larynx; the middle one (*g*, *fig.* 151) is of an oblong form, and varies in size, being larger than the lateral ones in the *Anatidæ*, but smaller in the *Insessores*. The lateral pieces are connected at one extremity with the thyroid piece, and at the other to the middle oblong piece above described, which completes the circle of the laryngeal frame-work posteriorly. Carus regards the first two incomplete tracheal rings (*gg*) as the anterior part of the cricoid. The arytenoid bones (*h*) rest upon the middle oblong portion of the cricoid, and extend forwards, being connected at their outer edge by means of elastic cellular substance to the thyroid bone, and attached by their anterior extremities to the uro-hyal bone by means of two small ligaments:* they form, by their inner margins, the *rima glottidis* or laryngeal fissure.

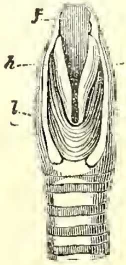
This fissure (*i*, *fig.* 152) being thus bounded by inflexible rigid substances is only susceptible of having its lateral diameter varied according to the degrees of separation or approximation to which the arytenoid bones are subject. These different states are produced by appropriate muscles, one pair of which may be regarded as analogous to the *Thyreo-arytenoidei*, and the other may be termed *Constrictores glottidis*. The former of these muscles (*k k*, *fig.* 174,) arise from the sides and posterior surface of the thyroid bone, and are inserted into the whole length of the inner edge of the arytenoid cartilages, which they draw outwards, and consequently open the laryngeal fissure. The *constrictores glottidis* in the Gigantic Crane arise from the middle of the internal or posterior surface of the thyroid bone, and are inserted into the extremities of the arytenoid pieces.

Fig. 174.



According to Mr. Yarrell, from whose Memoir the subjoined figures are taken, the constrictors of the glottis (*l*, *fig.* 175) "pass from the upper portion of the cricoid (thyroid) cartilage along the crura of the arytenoid cartilages, upon each outer edge of which they are inserted."† In either case these muscles are enabled to close the laryngeal opening with considerable force, and with such accuracy as to supersede the necessity of an epiglottis. From the simplicity of the structure just described, from the situation of the superior larynx with relation to the rictus or gape of the bill, and from the absence of lips by which this might be partially or

Fig. 175.



* On relating this fact to Mr. Clift, he suggested another use of the air-cells which is more generally applicable, namely, that of assisting the actions of the muscles by compressing and bracing them, in a manner analogous to the action of the fasciæ of the extremities in Man.

† Jacquemin, Mémoire sur la pneumaticité des oiseaux, 1835.

* Linn. Trans. vol. xvi. p. 306, pl. 17, figs. 3 and 4.

† This description is taken from the Gigantic Crane.—*Ciconia Argala*.

entirely closed, it is plain that it cannot be considered as influencing the voice, otherwise than by dividing or articulating the notes after they are formed by the lower larynx. The superior larynx presents, indeed, but few varieties in the different species of Birds; and these relate chiefly to certain tubercles which are observed in its anterior, but which vary in number, and do not exist at all in some species, as the singing birds; being chiefly present in those birds which have a rough unmusical voice. In the Pelecan, the Gigantic Crane, and most of the *Rasores*, a process extends backwards into the cavity of the upper larynx from the middle of the posterior surface of the thyroid cartilage, and seems destined to give additional protection to the air-passage.

The *trachea* (*G*, *fig.* 170, 171) in Birds is proportionally longer, in consequence of the length of the neck, than in any other class of animals, its length being further increased in many species by convolutions varying in extent and complexity. A species of Sloth (*Bradypus tridactylus*) among Mammalia, and a species of Crocodile (*Crocodilus acutus*) among Reptiles, present an analogous folding of the trachea.

The trachea is composed in Birds of a series of bony, and sometimes, as in the Ostrich, of cartilaginous rings, included between two membranes. In those cases in which they are of a bony structure, the ossification is observed to commence at the anterior part of each ring, and gradually to extend on both sides to the opposite part.

The tracheal rings, whether bony or cartilaginous, are, with the exception of the two uppermost, always complete, and not, as in most quadrupeds, where the windpipe bears a different relation to the organ of voice, deficient posteriorly. They differ in shape, being sometimes more or less compressed. They are generally of uniform breadth, but in some species are alternately narrower at certain parts of their circumference and broader at others, and in these cases the rings are generally closely approximated together, and, as it were, locked into one another. This structure is most common in the *Grallatores*, where the rings are broadest alternately on the right and left sides: the French Academicians have given a good illustration of this structure from the trachea of the Demoiselle Crane.

With respect to the diameter of the tracheal rings, this may sometimes be pretty uniform throughout, and the trachea will consequently be cylindrical, as in the *Insessores*, the *Grallatores* which have a shrill voice, the females of the *Natatores*, and most *Raptores* and *Rasores*: or the rings may gradually decrease in diameter, forming a conical trachea, as in the Turkey, the Heron, the Buzzard, the Eagle, the Cormorant, and the Gannet; or they may become wider by degrees to the middle of the trachea, and afterwards contract again to the inferior larynx; or, lastly, they may experience sudden dilatations for a short extent of the trachea;—the Golden-eye (*Anas clangula*), the Velvet-duck (*Anas fusca*), and the Merganser (*Mergus serrator*), present a single enlargement of this kind, in which the bony rings are entire, and of the same texture as in the rest of the tube. In the Golden-Eye the trachea is four times larger at the dilatation than at any other part. In the Goosander (*Mergus merganser*), the trachea presents two sudden dilatations of a similar structure to that above described. The trachea of the Emeu (*Dromaius ater*) is also remarkable for a sudden dilatation, but in this instance the cartilaginous rings do not preserve their integrity at the dilated part, but are wanting posteriorly, where the tube is completed by the membranes only.

The *bronchi* (*v*, *fig.* 163) are straight, compressed, delicate, and easily lacerable tubes; their rings, in most Birds,* form only a small segment of a circle, and are situated at the outer side of the tube, which is convex; the inner side is completed by a membrane (*membrana tympaniformis*) extended between the extremities of the defective rings, and is flat. The bronchial rings are weak and thin; in Birds without true muscles of voice, they are either of uniform thickness, or become gradually thinner to their termination: in many Birds which have the vocal muscles they grow suddenly thinner below the insertion of those muscles: this is remarkable in Owls.

The muscles of the trachea are generally a single pair, the *sterno-tracheales*, to which, in some cases, a second pair is added, the *cleido-tracheales*. The sterno-tracheales, which are analogous to the *sterno-thyroidei* of mammalia, arise from the costal processes of the sternum, and ascend along the sides of the trachea, as far in general as the superior larynx. The *cleido-tracheales* (*ypsilo-trachéens* of Cuvier) arise from the furculum or conjoined clavicles, and pass along the sides of the trachea parallel to the preceding.

Many birds possess only the tracheal and superior laryngeal muscles, and have no proper muscles of the inferior larynx. Cuvier† divides such birds into those which have the lower larynx simple or without dilatations, as the *Rasores*, and into those which have lateral bony cavities at that part, as the males of the Genus *Anas*, Cuv. and *Mergus*.

His next division in the order of complexity of the vocal organs includes those birds which have one pair of vocal or inferior laryngeal muscles, the *Broncho-tracheales*; these arise from the sides of the lower part of the trachea, and are inserted in one of the half-rings of the bronchi at a less or greater distance from the lower larynx in different birds; as, for example, in the first half-ring in the Genus *Falco*, in most of the *Grallatores*, in the Genus *Larus* (Gull), and *Phalacrocorax* (Cormorant); in the third half-ring in the King-fisher (*Alcedo*), and Goat-sucker (*Caprimulgus*); in the fifth half-ring in the Genus *Ardea*, Cuv. in the *Cuckoo* and the Eagle-Owl (*Bubo maximus*); in the *seventh* half-ring in the

* In the Vultures, which have no true vocal muscles, but only the *sterno-tracheales*, the first four bronchial rings are entire.

† Anat. Comparée, tom. iv. p. 450.

Barn-Owl (*Strix flammea*) and Horn-Owl (*Otus aurita*). The influence of these muscles upon the voice must obviously be in proportion as they shorten the bronchi and depress the lower larynx, according to the different insertions above mentioned.

A further degree of complexity in the organ of voice is presented by the *Psittacidæ* or Parrot-tribe, which, according to Cuvier, have three pairs of inferior laryngeal muscles.

The *Insessores*, lastly, present five pairs of muscles appertaining to the lower larynx, and the organ of voice consequently attains its greatest perfection in this order.

The peculiar structure of the lower larynx, and the modifications of the trachea in relation to its functions, will be treated of under the article *Organs of Voice*.

Urinary Organs.—These consist in birds of the kidneys, ureters, and a urinary receptacle, which is more or less developed in all birds.

The kidney of the oviparous vertebrate animal is distinguished from that of the mammiferous by the homogeneity of its substance, which is not divided into a cortical and medullary part, and by the tubuli uriniferi extending to the surface of the gland there to form by reiterated unions the ureter, and not terminating in a cavity or pelvis in the interior of the kidney, from which the ureter commences.

The *kidneys* (*x x*, *fig.* 182) of birds manifest all the essential characters of the oviparous type of structure. They are two in number, of an elongated form, commencing immediately below the lungs, and extending along the sides of the spine as far as the termination of the rectum; in which course they are impacted in, and as it were moulded to the cavities and depressions of the pelvis. From this fixed condition it results that they are generally symmetrical in position, not placed one higher than the other, as in the mammalia. The posterior surface of the kidney presents inequalities corresponding to the risings and depressions of the pelvis; the anterior surface is smoothly convex or flattened; but rising into a series of prominences which correspond, not to the eminences, but to the cavities of the bones on which they rest: their inner or mesial side is generally pretty regular and straight, but the external edge is more or less notched.

From the nature of the integuments about to be described, and the small amount of cutaneous transpiration in birds, the office of removing from the system the superfluous watery part of the circulating fluids devolves almost exclusively upon the kidneys, and they are consequently relatively larger than in the terrestrial mammalia.

The kidneys vary in size in different birds, being for example smaller in most of the *Grallatores*, as the Bustard and Heron, where the pelvis is short, than in the *Rasorial* Order, in which it is of great extent. Where they are short they are in general more prominent, and this is so remarkable in some birds, as the Owls, that in them they resemble somewhat in their superficial position the kidneys of mammalia.

As might be expected from their relations to the pelvis, the kidneys in birds present as many varieties of outward configuration as there are differences in the part of the skeleton to which they are moulded. In some aquatic birds, as the Grebe (*Podiceps*) and the Coot (*Fulica*), the kidneys are more or less blended together at their lower extremities, as in most fishes. In the rest of the class they are distinct from one another.

In the *Tern* they are each divided by fissures into seven or eight square-shaped lobes. In the *Eagle* they each present four divisions; but in these cases there are not distinct ureters to each lobe as in the subdivided kidneys of mammalia.

The principal lobes are in general three in number, the anterior or highest one being, in some cases, the largest; while in others, as the Pelecan, the contrary obtains, the lowest division being most developed in this bird.

In the Emeu (*Dromaius ater*) the kidney presents only two lobes; the superior or anterior one is the broadest and most prominent, being of a rounded figure, and constituting one-third of the whole; the lower division is flattened, and gradually tapers to a point. In the specimen we dissected we found the left kidney half an inch longer than the right.

Each kidney is invested by its proper capsule, a thin membrane, which also extends into the substance of the gland, between its divisions: a delicate layer of peritoneum is reflected over their anterior surfaces.

The texture of the kidneys is much more frail than in mammalia, readily yielding under the pressure of the finger, to which they give a granular sensation as their substance is torn asunder.

In colour they resemble the human spleen. Besides being divided into lobes, the surface of the kidneys may be observed to be composed of innumerable small lobules, separated by continuous gyrations like the convolutions of the cerebral substance. The ultimate divisions of the lobules and their intimate structure can only be distinguished by observations on the embryo, unless when the component follicles are filled, as they occasionally are seen to be after death, with the white salts of the urinary secretion. The *tubuli uriniferi*, as Müller observes,* may then be seen under the microscope originating from every part of the internal substance of the lobules, extending to the gyrations, uniting in the pinnatifid form, and coursing to the margins of the lobules, all the inflexions of which they follow. The pinnatifid ramification of the uriniferous tubules is sometimes *opposite*, sometimes *alternate*. Sometimes the branches are simple, sometimes dichotomously divided: but these ramuli appear scarcely smaller than the branches from which they spring, and never intercommunicate. They have been successfully injected with size and vermilion, without any of this material escaping into the secerning vessels, which are much more minute. The uriniferous ducts, when thus traced from the

* De Glandularum Structurâ, p. 92.

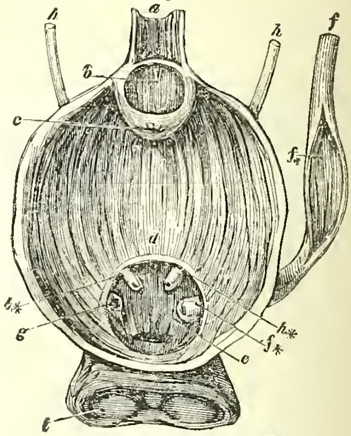
trunks to the branches, are seen to become conjoined in pyramids, which adhere to the branches of the ureter, are sent out in the gyri of the lobules, and are outspread in a pinnatifid figure on the surface, one next another, and ultimately terminate in blind, rounded, but not dilated extremities. The branches from the convoluted lobules unite dichotomously, and ultimately escape by a single duct—the ureter.

The arteries and veins of the kidneys have already been described; a difference of opinion, however, prevails as to the course of the blood in the veins which pass from the lower end of the kidneys (at *v*, *fig.* 171) to the hypogastric vein (*z*). Jacobson considers that the venous blood is carried into the kidney by these veins, for the purpose of affording the material for the urinary secretion, analogous to the portal vein in the liver; but Cuvier regards these veins as having the same function as those which come from the upper ends of the kidneys, and that they return the blood from the lower ends of the kidneys to aid in the formation of the portal vein. Nicolai* also opposes the doctrine of a venous circulation in the kidneys of Birds. In favour of Jacobson's theory is the small size of the renal arteries, in consequence of which the kidneys are not more coloured than the liver, when the arterial system is injected from the aorta, and the disproportionate size of the veins, together with the analogy of the cold-blooded *ovipara*, in which the existence of a secreting system of veins in the kidneys is now generally admitted.

The *ureter* (*y*, *fig.* 163, 182; *h*, *h*, *fig.* 176) has the same structure as in the mammalia. It is continued down along the anterior surface of the kidney towards the mesial side; here and there imbedded in its substance, forming a series of dilatations corresponding to the principal lobes or enlargements of the gland, and receiving the branches of the tubuli uriniferi as it passes along. But these slight reservoirs do not present any parts corresponding to the mammillæ and their infundibula of mammalia. Below the kidney the ureters pass behind the rectum, becoming connected to, and after a short distance involved in its coats; they ultimately terminate upon valvular eminences, in a depression at the lower part of the urinary sac; the terminal papillæ of the ureters are situated with the orifices of the genital ducts, in the same segment of the cloaca, which is therefore termed the urethro-sexual cavity (*e*, *fig.* 176).

The space intervening between the urethro-sexual cavity and the valvular termination of the rectum (*c*, *fig.* 176) forms a cavity more or less developed in different birds, but always distinct in the smoothness of its lining membrane from the rectum, which has a more vascular and villous internal tunic. The birds in which this rudimental urinary bladder presents the largest capacity are the Owls, many of the aquatic birds, as the Pelecan, Willock, Grebe, Swan, &c.; some of the Wading Order, as the Bittern and Bustard, but more especially the Ostrich, among the *Cursores*, in which the urinary receptacle is represented as laid open (*d*, *fig.* 176).

Fig. 176.



*Cloaca of the Ostrich.**

The *Supra-renal Glands*, *Renal capsules*, *Glandulæ succenturiatæ* (*d*, *d*, *fig.* 182) are small bodies, usually of a bright yellow colour, situated on the mesial or inner side of the superior extremities of the kidneys; closely attached to the coats of the contiguous large veins and in contact with the testes in the male; and the left one adhering to the ovary in the female. They vary in shape, being sometimes of a round, flattened, oval, or irregularly triangular figure. They are proportionally smaller than in mammalia, being in the Goose each about the size of a pea.

They present, like the kidneys, a homogeneous texture throughout, and do not exhibit the alternate strata of different-coloured substances as in mammalia. In the Gigantic Crane we found the texture of the supra-renal glands to be coarsely fibrous; in the Hornbill they were granular, similar to the kidney; in the Pelecan they were of a granular but more pulpy texture.

There is no cavity in the supra-renal glands. The veins which return the blood from them are of proportionally large size, as in all the parenchymatous bodies without excretory ducts. The supra-renal glands have been found to present a slight enlargement corresponding with the increased development of the sexual organs; and it has been conjectured that their function is related to that of the generative system.

Thyroid Glands. In many birds, as the Vultures, Falcons, Starling, Magpie, Heron, Bustard, and in most Aquatic birds, two glands are found, one on each side of the trachea, very near the lower larynx and frequently attached to the jugular veins. They are regarded as the analogues of the thyroid glands. In addition to these there are two small glands, in the Gannet, attached to the upper part of the commencement of each bronchus.

* Oken's Isis, 1826, p. 414.

* From Memoires du Muséum, tom. xv. pl. 2, *fig.* 1.

Peculiar Secretions.—The unctuous fluid with which Birds lubricate their feathers is secreted by a gland which is situated above the coccyx or uropygium. This gland consists of two lateral moieties conjoined. As might be expected, it is largest in the birds which frequent the water. In the *Swan* it is an inch and a half in length, and has a central cavity, which serves as a receptacle for the accumulated secretion; but this cavity has not been observed in other species. Each lateral portion is of a pyriform shape, and they are conjoined at the apices, which are directed backwards and are perforated by numerous orifices. The longitudinal central cavities also present internally numerous angular openings, in which there are still smaller orifices. The surrounding glandular substance consists of close-set almost parallel straight tubules, and is not irregularly cellular. The tubules extend to the superficies of the gland, without ramifying or intercommunicating, and preserve an equable diameter to their blind extremities. The tubules are longest at the thickest part of the gland, and become shorter and shorter towards the apex.

Tegumentary system.—This is composed, as in Mammalia and Reptilia, of the corium or derm, epiderm, and its appendages, and an intermediate layer of unhardened epiderm with colouring matter, called *rete mucosum.*

The *corium*, or true skin, is very thin, as in the cold-blooded Ovipara. It adheres to the subcutaneous muscles by cellular tissue, which is frequently the seat of accumulation of dense yellow fat; and it is moved by muscles which at the same time raise and ruffle the plumage which it supports.

The *rete mucosum* rarely contains any colouring matter where the feathers grow; at this part the skin is of a pale, greyish colour, or pink, from the colour of the blood which circulates in it. But in the naked parts of the integument, as the cire, the lore, the comb, the wattles, the naked parts of the head and neck in some birds, and the tarsi and toes, the rete mucosum frequently glows with the richest crimson, orange, purple, green, black, and a variety of other tints, of which the *planches coloriés* and the different zoological monographs of families of birds afford numerous examples.

The *epidermis* is in some places continued as a simple layer over the corium, following its wrinkles and folds, as around the naked necks of some Vultures. It is moulded upon the bony mandibles to form the beak, and in some birds adheres to osseous protuberances on the cranium, where it forms a species of horn; and it is remarkable that these instances occur chiefly in those orders of birds, the *Cursores* and *Rasores*, which are most analogous to the Ruminantia among quadrupeds: the Cassowary and Helmeted Curassow are examples. The cuticle is sometimes developed into spines or spurs, as upon the wing of the Secretary-bird, Cassowary, the *Apteryx*, and the *Palamedea*; and upon the tarsi of the Gallinaceous Birds. The claws which sheath the ungueal phalanges of the feet assume various forms adapted to the habits and manner of life of the different orders. A remarkable artificial form is given to the claw of the middle toe in certain birds; the inner edge being produced and divided into small parallel processes like the close-set teeth of a comb (*fig.* 132.) These teeth are not reflected or recurved, as they might be expected to be, if they had been intended to serve as holders of a slippery prey, but are either placed at right angles to the claw or are inclined towards its point. The Common Barn-Owl (*Strix flammea*), the Goat-sucker genus (*Caprimulgus*), the Heron and Bittern kind (*Ardeidæ*, Vig.), afford examples of this structure; and as each species of bird appears to be infested by its peculiar louse (*Nirmus*), the solution of the final intention of so singular a contrivance, which is limited to so few species, and these of such different habits, may yet be afforded by the entomologist. At least it would be worth while to examine the parasitic animals of the species so provided, with the view of determining whether they possessed superior powers of adhesion which might require the application of a comb in the birds infested by them.*

With respect to the scales which defend the naked parts of the legs of birds, they do not differ from those of Reptiles. Their form and disposition, as has been already observed, have afforded distinctive characters to the zoologist. In most of the *Raptores*, the *Psittacidæ*, the *Rasores*, the *Grallatores*, and the *Natatores*, the scales are polygonal, small, and disposed in a reticulate form; the birds so characterized formed the *Retipedes* of Scopoli. In the rest of the class the tarsi are covered anteriorly with unequal semi-annular scales, ending on each side in a longitudinal furrow, and these birds were termed the '*Scutipedes*.'†

The four classes of vertebrate animals have each their characteristic external covering: the cold-blooded Ovipara are naked, or their external surface is defended only by hard scales or plates (*squamæ* and *scutæ*); but the warm-blooded classes require to be invested by an integument better adapted to maintain the high degree of temperature peculiar to them: hence quadrupeds are clothed with fur and hair, and birds with down and feathers.

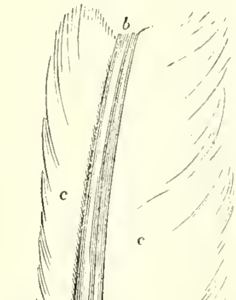
Feathers are the most complicated of all the modifications of the epidermic system, and are quite peculiar to the class of birds. The eloquent Paley well observes that " every

* Mr. Swainson objects to the theory which ascribes to the serrated claw the function of freeing the plumage from vermin, because its presence is partial in the class of Birds. " To suppose," says he, " that nature has given to one or two families of birds the exclusive power of freeing themselves from an enemy which in like manner infests *all* birds, is preposterous." The assertion that the different species of *Nirmi* infest all birds *in like manner* is much easier than the proof.

† In one section of the *Tyranni*, Cuv. the scutæ surround the tarsi as complete rings. Where the carneous parts of the muscles are continued low down upon the legs, as in the Owls, a covering of feathers is co-extended to preserve their temperature.

feather is a mechanical wonder;" "their disposition, all inclined backward, the down about the stem, the overlapping of their tips, their different configuration in different parts, not to mention the variety of their colours, constitute a vestment for the body, so beautiful, and so appropriate to the life which the animal is to lead, as that, I think, we should have had no conception of any thing equally perfect, if we had never seen it, or can now imagine any thing more so."

Fig. 177.*

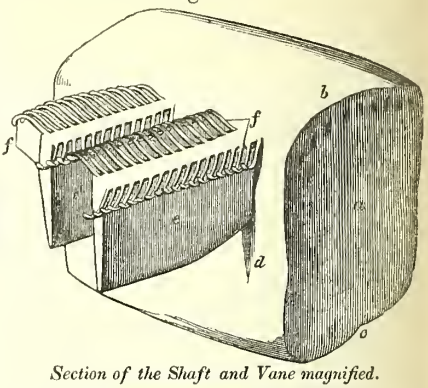


Notwithstanding the varieties of size, consistence, and colour, all feathers are composed of a *quill* or *barrel* (*a*, *fig.* 177), a *shaft* (*b b*), and a *vane* or *beard* (*c c*); the vane consists of *barbs* (*e e*, *fig.* 178) and *barbules* (*f f*, *fig.* 178).

The *quill*, by which the feather is attached to the skin, is larger and shorter than the shaft, is nearly cylindrical in form and semi-transparent; it possesses in an eminent degree the opposite qualities of strength and lightness. It terminates below in a more or less obtuse extremity, which is pierced by an orifice termed the *lower umbilicus* (*e*, *fig.* 177); a second orifice, leading into the interior of the quill, is situated at the opposite end, at the point at which the two lateral series of barbs meet and unite; this is termed the *upper umbilicus* (*f*, *fig.* 177). The cavity of the quill contains a series of conical capsules fitted one upon the other, and united together by a central pedicle.

The *shaft* is more or less quadrilateral, and gradually diminishes in size from the upper umbilicus to its distal extremity. It is always slightly bent, and the concave side is divided into two surfaces by a middle longitudinal line continued from the upper umbilicus; this is the *internal surface* (*c*, *fig.* 178). The opposite, or *external surface* (*b*, *fig.* 178), is smooth, and slightly rounded; both sides are covered with a horny material similar to that of which the quill is formed, and they inclose a peculiar white, soft, elastic substance, called the *pith* (*a*, *fig.* 178).

Fig. 178.*



Section of the Shaft and Vane magnified.

The *barbs* are attached to the sides of the shaft near the external surface, and consist of laminæ, varying as to thickness, breadth, and length. They are arranged with their flat sides towards each other, and their margins in the direction of the external and internal sides of the feather; consequently they present a considerable resistance to being bent out of their plane, although readily yielding to any force acting upon them in the line of the stem: *e e*, *fig.* 178, are the bases of the barbs of a feather magnified. The *barbules* (*f f*, *fig.* 178) are given off from either side of the barbs, and are sometimes similarly barbed themselves, as may be seen in the barbules of the great feathers of the Peacock's tail.

Sometimes, as in these feathers and in the plumes of the Ostrich, the barbules are long and loose; but more commonly they are short and close-set, and by their form and disposition constitute the mechanism by which the barbs are united together. The barbules arising from the upper side of the barb, or that next the extremity of the feather, are curved downwards or towards the internal surface of the shaft; those which arise from the under side of the barb are curved in the contrary direction: so that the two adjoining series of hooked barbules lock into one another in a manner which the Parisian dissectors compare to the fastening of a latch of a door into the catch of the door-post.

But besides the parts which constitute the perfect feather, there is also an appendage attached to the upper umbilicus of the quill which requires to be noticed. This is termed the *accessory plume*. It is usually a small downy tuft, but varies both in different species, and even in the feathers of different parts of the body of the same bird. In the quill-feathers of the wings and tail, it usually remains in the rudimentary state of a small tuft of down; but in the body-feathers of Hawks, Grouse, Ducks, Gulls, &c. it is to be found of all sizes, acquiring in some species a size equal to that of the feather from which it is produced.

* This figure and *fig.* 179, 180, 181, are copied from the Monograph of F. Cuvier, "Sur le developpement des Plumes," Mémoires du Muséum, tom. xiii.

* Perrault, Hist. Nat. des Animaux, p. 336.

In the Ostrich the feathers have no accessory plume: in the Rhea it is represented by a tuft of down; in the Emeu, on the contrary, the accessory plume equals the original feather, so that the quill supports two shafts; and in the Cassowary, besides the double feather, there is also a second accessory plume, so that the quill supports three distinct shafts and vanes.

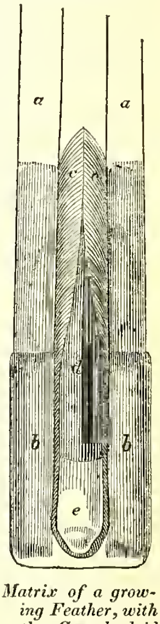
The feathers vary in form in different parts of the bird according to their functions, and afford zoological characters for the distinction of species; they have, therefore, received in Ornithology distinct names. Those which surround or cover the external opening of the ear are termed 'auriculars.' Those which lie above the scapula and humerus are called the 'scapulars.' The small feathers which lie in several rows upon the bones of the antibrachium are called the 'lesser coverts' *(tectrices primæ)*. Those which line the under or inner side of the wings are the 'under coverts.' The feathers which lie immediately over the quill-feathers are the 'greater coverts' *(tectrices secundæ)*. The largest quill-feathers of the wing, which arise from the bones of the hand, are termed 'primaries' *(primores)*. Those which rise from the ulna, towards its distal end, are the 'secondaries' *(secondariæ)*. Those which are attached to its proximal extremity are the 'tertiaries' *(tertiariæ)*. These in some birds, as the Woodcock and Snipe, are so long as to give them the appearance, when flying, of having four wings. The quill-feathers which grow from the phalanx, representing the thumb, form what is termed the bastard wing *(alula spuria)*.

In considering the structures which determine the powers of flight in different birds, it is necessary to take into account the structure, forms, and proportions of the wing-feathers, as well as the development of the bones and muscles which support and move them; as much depends upon the mechanical advantages resulting from the shape and texture of the expanded wing. When the primary quill-feathers gradually increase in length as they are situated nearer the extremity of the pinion, they give rise to the acuminated form of wing, as in the true Falcons, in which the second primary is the longest. In the Hawks the wing is of a less advantageous form, in consequence of the fourth primary being the longest; when the primaries gradually decrease in length towards the end of the pinion, they give rise to a short rounded form of wing, such as characterizes the Gallinaceous Order; in which, although the pectoral muscles are immensely developed in order to counteract the disadvantage resulting from the disposition of the primaries, yet they are only able, in consequence of the form of the wing, to carry the bird rapidly forward for a short distance, and that with an exertion and vibratory noise well known to every sportsman.

The texture of the quill-feathers has also a material effect on the powers of flight. In the Falcons each primary quill-feather is elongated, narrow, and gradually tapers to a point; the webs are entire, and the barbs closely and firmly connected together.* In the Owls the plumage is loose and soft, and the outer edge of the primaries is serrated; so that, while they are debarred from a rapid flight, which would be dangerous in the gloom in which they go abroad, they are enabled, by the same mechanism, to wing their way without noise, and steal unheard upon their prey.

Development of feathers.—The first covering of the bird is a partial and temporary one, consisting of fasciculi of long filaments of down, which on their first appearance are enveloped in a thin sheath, but this soon crumbles away after being exposed to the atmosphere. The down-fasciculi, which diverge each from a small quill, are succeeded by the feathers, which they guide, as it were, through the skin: and after the first plumage, at each succeeding moult, the old feathers serve as the gubernacula to those which are to follow. It is to be observed that feathers do not grow equally from every part of a surface of a bird; they are not developed, for example, at those parts which are subject to friction from the movements of the wings and legs. They first appear in clumps upon those parts of the skin which is least affected by the pressure of superincumbent parts, or the movement of the parts beneath, as upon the head, along the spine, upon the exterior surface of the extremities, at the intervals of the joints on either side the projecting sternum, and at the sides of the abdomen.

Fig. 179.



Matrix of a growing Feather, with the Capsule laid open.

The matrix, or organ by which the perfect feather is produced, has the form of an elongated cylindrical cone, and consists of a capsule, a bulb, and intermediate membranes which mould the secretion of the bulb into its appropriate form. The matrix is at first an extremely minute cone, attached by a filamentary process to a follicle or papilla of the skin; but it is not a development of that part, being of a different structure and adhering to it by a small part only of its circumference. The matrix progressively increases in length; its base sinking deeply into the corium, and acquiring a more extended connection by enlarged vessels and nerves, while its apex protrudes to a greater or less extent from the surface of the integument, when the capsule drops off to give passage to the feather which it incloses, and the formation of which has, in the meanwhile, been

* Of so much consequence are the quill-feathers to the Falcons, that when any of them are broken the flight is injured and the falconers find it necessary to repair them; for this purpose they are always provided with perfect pinion and tail feathers, regularly numbered.

gradually proceeding from the apex downwards. The capsule of the matrix (*a a*, *fig.* 179) is composed of several layers, the outermost of which is of the nature of epidermis; the inner ones are more compact, but have no appearance of organization. The sides of the capsule which correspond to the outer and inner sides of the growing feather within are indicated by a white longitudinal line.

The axis of the capsule is occupied by a medulla or bulb, (*e*, *fig.* 179,) also of a cylindrical form, and of a soft fibrous texture, adhering by its base to the parts beneath, and there receiving numerous bloodvessels and a nerve.

Between the medulla and the capsule there are two parallel membranes, one internal (*d*, *fig.* 179); the other external, (*b*, *fig.* 179); from the latter membrane a number of close-set parallel laminæ extend obliquely from one of the white longitudinal lines above mentioned to the other on the opposite side of the cylinder. The two membranes seem to be united together by the oblique septa. In the long and narrow spaces between these septæ, the matter of the vane (*c*. *fig.* 179) is deposited, and formed into barbs and barbules, nearly in the same way as the enamel of the teeth is formed between the external membrane of the pulp, and the internal membrane of the capsule. The deposition of the material of the barbs commences at the apex of the bulb, and the stem is next formed in the following manner.

The external longitudinal line from which the oblique laminæ are continued, receives and moulds on the inner surface of the external capsule the horny covering of the back of the feather, or that longitudinal band, to the two sides of which the barbs are attached; and on the opposite surface of the internal membrane are formed the pith or substance of the shaft, and the horny pellicle which incloses it on the inner surface. The internal longitudinal line has no other use than to establish a solution of continuity between the extremities of the barbs of one side and those of the other, which meet at that part, and thus curve round and completely inclose the formative bulb. In *fig.* 180, the capsule of the matrix of a growing feather has been laid open, and the nascent barbs (*c*) which surrounded the bulb have been unfolded, exposing that part at *a b*. A portion of the barbs and stem have been completed and protruded, and the bulb is beginning to undergo a process of absorption at that part, which will hereafter be described. The shaft and barbs at the apex of the cylinder are the first parts which acquire consistence, and the molecules composing the remainder are less compactly aggregated as they are situated nearer the base of the matrix. As the gelatinous medulla increases at the base, the first-formed shaft and barbs are protruded through the extremity of the capsule, the bulb continuing to furnish the secretion which is moulded between the two striated membranes until the entire feather is completed. If the striated membrane inclosing the bulb be attempted to

Fig. 180.

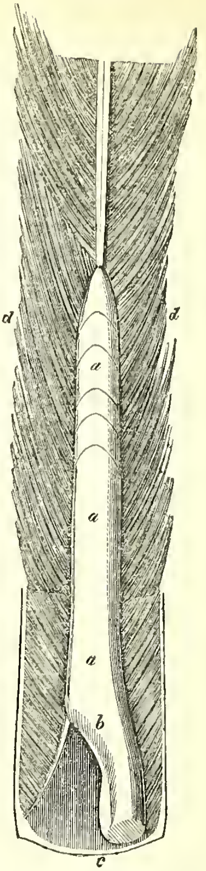
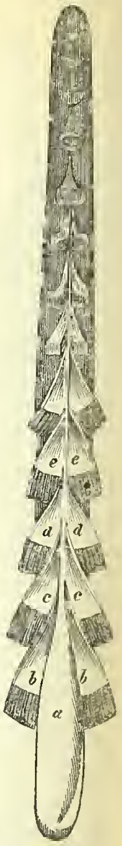


Fig. 181.



Structure of the Bulb.

be reflected from below upwards, it will be found to be connected with a series of membranous cones (*a b c d e*, *fig.* 181,) ranged one upon the other throughout the whole length of the bulb, and connected together by a tube running through its centre. In this figure (181) the pulpy matter which occupied the interspaces of the cones has been removed to shew their central connecting tube.

As the development of the feather advances, the pulpy matter disappears from the summit of the medulla, and only the membranous funnel-shaped caps remain, which are protruded from the theca and the centre of the new-formed barbs, and fall off as these expand. The theca which incloses the whole is of a firm texture where the new moulded barbs are yet pulpy and tender, but it becomes thinner as these acquire consistency, and lastly, dries and crumbles away after it has been exposed to the action of the atmosphere. The bulb itself, when examined in a half-formed quill-feather,* is composed of two parts corresponding to the external and internal aspects of the feather. The internal part represents a semi-cylinder or case, in

* The following description is taken from such feather in the goose.

closing the external part, which is of a conical form; the latter extends from the base of the bulb, and gradually diminishes to a point where the shaft is completed and the barbs begin to expand. Its office is to deposit the pith within the shaft, and it is absorbed in proportion as this is effected. The internal part or case also commences at the base of the bulb, and adheres closely to the cone, with which, indeed, its substance is continuous; it increases in thickness as the cone diminishes, its margins are beautifully scolloped or crenate, and the crenations are lodged in the interspaces of the oblique laminæ or moulds, and deposit in them the material of the vane. The horny sides of the shaft are lodged and formed in the grooves between the external and internal parts of the bulb, and correspond in degree of formation to the depths of those grooves, and being progressively brought into contact from above downwards, the shaft is thus completed, leaving the longitudinal line at the internal side. When all the grooves, (wherein are formed the barbs, and the portion of the shaft which carries them) are filled by the horny matter, and the barbed part of the feather is finished, this horny matter lastly expands uniformly around the medulla, and forms the quill of the feather.

When the quill of the feather has acquired the due consistence, the internal medulla becomes dried up, and is resolved, as before, into membranous cones arranged one upon the other; but these latter never pass out, for the quill, which is now hardened and closed by the shaft at the opposite extremity to the lower umbilicus, will not permit their egress; they remain, therefore, inclosed, and constitute the light dry pith which is found in the interior of the quill. The last remains of the bulb are seen in the ligament which passes from the pith through the lower opening of the quill and attaches it to the skin.

Cuvier has justly observed that notwithstanding the complexity of the process just described, the formation of a feather differs only from that of a tooth in the nature of the substance which is deposited between the two tunics which constitute its mould; but a tooth takes many years to be perfected, and there are but two series produced in one part of the jaw, and only one in the other, in any warm-blooded animal. Feathers, on the other hand, are developed in the course of some days; they attain a length of from one to two feet or more in many birds, and they are almost all renewed every year,—in many species even twice a year. It may be conceived, then, how much vital energy the organization of birds must exercise, and how many dangers must accompany so critical a period as that of the moult.

The plumage is commonly changed several times before it attains that state which is regarded as characteristic of the adult bird. The time required for this varies from one to five years, and several birds rear a progeny before they acquire the plumage of maturity.

When the male bird assumes a vestment differing in colour from the female, the young birds of both sexes resemble the latter in their first plumage; but when the adult male and female are of the same colour, the young have then a plumage peculiar to themselves. Mr. Yarrell states a third law in addition to the preceding, viz. that whenever adult birds assume a plumage during the breeding season decidedly different in colour from that which they bear in winter, the young birds have a plumage intermediate in the general tone of its colour compared with the two periodical states of the parent birds, and bearing also indications of the colours to be afterwards attained at either period.

"There are three modes," the same author observes, "by which changes in the appearance of the plumage of birds are produced:—

"By the feather itself becoming altered in colour.

"By the bird's obtaining a certain number of new feathers without shedding any of the old ones; and

"By an entire or partial moulting, at which old feathers are thrown off and new ones produced in their places.

"The first two of these changes are observed in adult birds at the end of spring, indicating the approach of the breeding season; the third change is partial in spring and entire in autumn.

"A fourth mode may be noticed, though its effects are limited. It is observable in spring, as the breeding season approaches, by the wearing off of the lengthened lighter-coloured tips of the barbs of the feathers on the body, by which the brighter tints of the plumage underneath are exposed, as was noticed by Sir William Jardine and Mr. Blyth. The effect is most conspicuous in the *Buntings*, *Finches*, and *Warblers*."*

The experiments detailed in the Memoir above quoted, some of which we witnessed, prove incontestably, that notwithstanding the extravascular nature of feathers, they are subject to influences, apparently of a vital nature, which occasion a change of colour in them after they are completely formed. In yearling birds the winter plumage which succeeds the autumnal moult gradually assumes the brighter tints characteristic of the adult without a change of feather. The new colour commences generally at that part of the web nearest the body of the bird, and gradually extends outwards till it pervades the whole feather.

Organs of generation. — The few varieties of structure which these organs present in the Class of Birds, are principally met with in those of the male, which we shall first describe.

The male organs of generation exhibit all the essential characteristics of the oviparous type of structure. The testes are situated high up in the abdomen, whence they never descend into an external scrotum. The intromittent

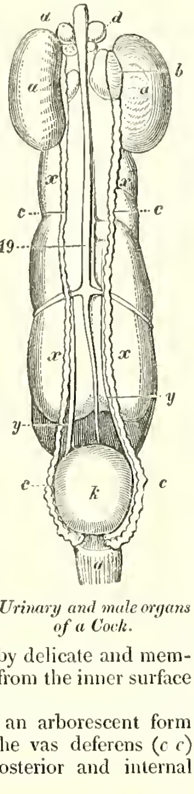
* Yarrell, Zool. Trans. i. p. 13.

organ is either double, as in Serpents, when, however, each penis is extremely small; or it is single, but in this case, to whatever extent it may be developed, it always consists of a uniform ligamentous and vascular elastic substance, and, as in the Tortoise, is simply grooved along the upper surface or dorsum for the passage of the fecundating fluid.

As there is no true urethral canal, so neither are the glands of Cowper or the prostatic glands present.

The *testes* (*x*, *fig.* 166, *a*, *a*, *fig.* 182) are two in number; in form more or less oval, situated above the upper extremities of the kidneys. They vary remarkably in colour in different birds; we may mention, as examples, that they are white in the Peregrine Falcon and and Dove; pale yellow in the Horn-Owl, and Gallinule; of a brighter yellow in the Magpie, Bay Ibis, Ruff, and Oyster-catcher; of a black colour in the Chough, Partridge, Heron, Sea-gull, but whitish towards the lower end in the last two. They are invested with a strong and dense *albuginean* tunic. Their structure is evidently tubular, the contorted tubules are very slender, scarcely exceeding in diameter the seminal tubules of mammalia: they are separated into packets by delicate and membranous septa, continued from the inner surface of the tunica albuginea.

Fig. 182.



Urinary and male organs of a Cock.

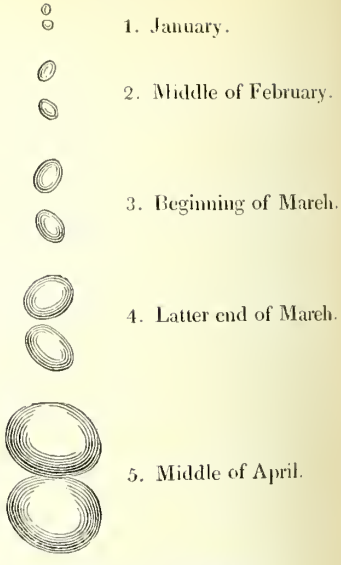
The arteries spread in an arborescent form beneath that capsule. The vas deferens (*c c*) is continued from the posterior and internal part of the gland.

The periodical variations of size which the testicles undergo are very remarkable in the Class of Birds; and the limited period during which their function is in activity is compensated by the frequency and energy with which it is exercised.

The proportional size which the testes acquire at the breeding season is immense, as may be seen in the subjoined figures (183) of the testes of the House-Sparrow;* which commences with the glands as they appear in January, when they are no bigger than pins' heads, and ends with their full development in April.

It rarely happens that both testes are developed in exactly the same degree, but the increase of size is not limited to the one on the left side. The right testis is as often the

Fig. 183.



Testes of the House-Sparrow.

largest, and we have seen an example, in a Rook, where it alone had taken on the action of sexual increase, and had acquired a bulk compensating for the want of development in the left testis.

In most Birds, the only appearance of an epididymis is a remnant of the Wolffian body or primordial matrix of the genital and urinary organs (*b*, *fig.* 182). This part frequently presents a colour strikingly different from that of the testes: thus it has been observed in the Bustard and Curassow to be black; in the Cassowary, yellow; and in the Anthropoides Virgo to be of a green colour.

In the Ostrich the epididymis is folded upon itself at the side of the testis.

The vas deferens commonly passes down to the cloaca by the side of the ureters without undergoing any remarkable convolution; but in the common Cock it is bent upon itself in short transverse folds from side to side almost from its commencement; the folds gradually but slightly increase as they approach the cloaca, both in extent and in the diameter of the tube composing them, and they are so closely compacted as to present in a longitudinal section the appearance of a series of cells, which are capable of retaining, as in a vesicula seminalis, a quantity of the seminal secretion.

Each vas deferens in the Common Cock terminates on a separate rudimentary penis or papilla, situated in the urethro-sexual division of the cloaca at a little distance from each other, and anterior to, or *sternad* of the insertions of the ureters.

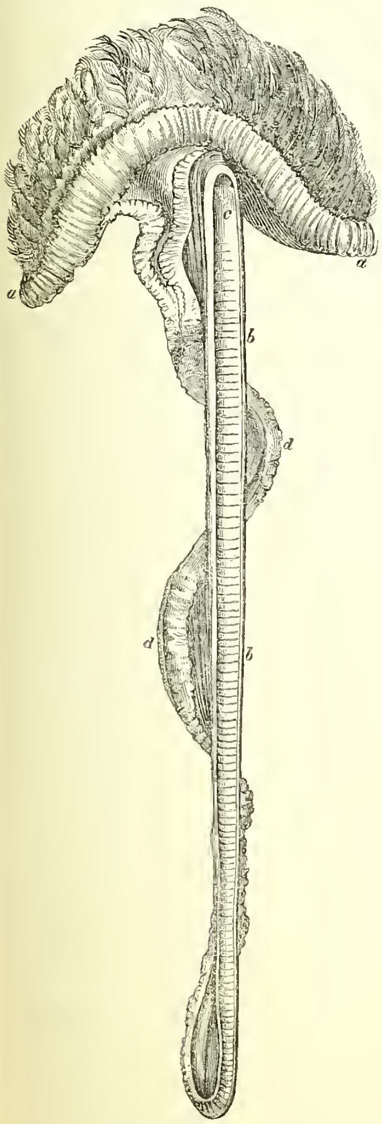
The base of each papilla is surrounded by a remarkable plexus of arteries and veins (*M*, *M*, *fig.* 171) which serve as an erectile organ during the venereal orgasm, when the turgid papillæ are

* See John Hunter, in the Animal Œconomy, plate vii.

everted, and the semen brought into contact with the similarly everted orifice of the oviduct in the female, along which the fecundating fluid is impelled by the vibrations of the cilia of the mucous surface through all the windings of that tube to its ultimate destination.

In the *Natatores* which copulate in water there is an obvious necessity for a more efficient coitus than a simple contact of everted cloacæ, and consequently in these birds, as the Swan, Gander, Drake, &c. a long, single penis is developed.

Fig. 184.



Penis of a Drake.

This body arises from the front part of the outer compartment of the cloaca (*a, a, fig.* 184) immediately below the urethro-sexual cavity; it is in the unexcited state coiled up like a screw from the elasticity of the internal ligamentous structure. The external coat is a production of the membrane lining the outer cavity, and gives off a number of small pointed processes, which in the Gander are arranged in transverse rows on either side the urethral groove, and near the extremity of the penis are inclined backwards. The body (*b b, fig.* 184, where it has been cut open) is composed of a white elastic ligamentous substance, and a vascular pulp, but without any of the cellular structure which characterizes a *corpus cavernosum.* A groove (*d d*), commencing widely at the base is continued along the side of the ligamentous substance, and follows all the spiral turns of the penis to its extremity. The vasa deferentia terminate in papillæ at the base of this groove, along which the semen is transmitted to the vagina of the female.*

The penis of the Ostrich is also single, and the urethra is represented by a dorsal groove; it is disposed in a slight spiral bend when in a retracted state. It arises by two strong ligamentous crura from the cartilage uniting the bones of the pubis, and descends into the external or preputial compartment of the cloaca. There are four muscles to the penis of the Ostrich: two arise from the inside of the os sacrum, and descending along the preputial cavity, are inserted into the base of the penis: two other muscles pass from the internal part of the iliac bones, to be attached to the sides of the penis.

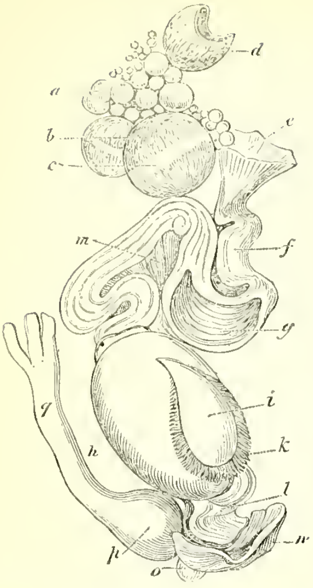
The Guan (*Penelope cristata*) presents a singular exception to the other Rasorial Birds in having a single linguiform pointed penis developed, the sides of which are provided with retroverted papillæ, as in the Anserine Birds. In the Gallinule, which seeks its food in water, there is no penis; it, therefore, most probably copulates on land.

The tumid margin of the preputial cavity of the penis is well provided with large mucous follicles which secrete a sebaceous lubricating substance; of these there are twelve in the Gander, arranged six on each side. These may be regarded as analogous to the *glandulæ odoriferæ;* but there is no vestige either of prostatic or other urethral glands.

Female organs of generation.—An ovarium or productive organ, (*a, b, c, d, fig.* 185,) with an oviduct or efferent tube (*e, f, g, k, l,*) are present in all birds, and a clitoris or organ of

* We cannot account for the error into which Sir Everard Home has fallen, in describing the urethra of the drake as a complete canal, and the penis as being enclosed within a prepuce. (Phil. Trans. 1802, pp. 361, 363.) Repeated dissections of different species of *Anas*, Cuv. have satisfied us of the accuracy of Mr. Hunter's statement, that "birds have no urethra, some having merely a groove, as the *Drake* and Gander, and many being even without a groove, as the common Fowl." Animal Œconomy, p. 40. The letter *c*, in Sir Everard Home's figure, (*fig.* 184,) points to the orifices of mucous glands or cut vessels, and not to the papillæ, on which the vasa deferentia terminate.

Fig. 185.



*Fowl.**

excitement is found in those species of which the males have a penis.

Birds differ from all the other oviparous vertebrata in having the canal which completes and carries out the ovum single, and in this respect they manifest an analogy to many mammalia. When, however, the whole of the circumstances from which this condition results come to be investigated, the nature of the part in the two classes will be found to be widely different.

In the Mammalia the single efferent canal results from a blending together of the vaginæ and uteri of the two sides of the body for a greater or less extent along the mesial line; which junction is continued from the external outlet towards the ovaria, but never extends beyond the uteri, the Fallopian tubes always remaining distinct. And in proportion as the generation approximates the oviparous mode, the efferent tubes remain separate for a greater extent. Thus, among the *Rodentia*, we find the uterus completely divided into two lateral tubes, as in the Rabbit; and in the *Marsupiata* the division is continued through the whole extent of the true vagina.

In the true Oviparous classes the oviducts are always double and open separately into the cloaca, and the exception in the class of Birds to this rule is only apparent.

At an early period of existence the two oviducts exist of equal size, but the left one alone attains that state of development which qualifies it for the exercise of the sexual functions. Hitherto no exception has been found to this rule, and the uniformity in the condition of the excluded ovum in Birds corresponds with the sameness which prevails in the structure of the organs concerned in its evolution.

The *ovarium* is in general single like the oviduct, and developed only on the left side, as in the *Rasores*. But two ovaria have been observed in many of the *Raptores*. In the Falcons Nitzsch found the right ovary more developed than the left, and also in some species of Eagle and Owl. In the Sparrow-Hawk the same distinguished anatomist found two ovaries equally well developed.

In the Common Fowl the *ovary* first makes its appearance as a membrane beset with small pellucid vesicles adhering to and apparently developed from the coats of the vena cava. The substance of the ovary is invested by a thin and extensible *capsula propria*, covered by a reflection of peritoneum. The ova are imbedded in a *stroma* of delicate and yielding cellular substance, and consist each of a minute pellucid vesicle, surrounded by the yolk, which at this period is as clear as the fluid of the vesicle itself, and both are inclosed in a distinct transparent capsule.

When the ovum has attained the diameter of a line, the vitelline liquid presents a turbid whitish appearance. When it is about the size of a pea the yolk begins to assume a slight straw-coloured tint, and the seat of this colouring matter may be observed to be certain globules of oil now superadded to the albuminous and serous fluid. As the oily material prevails, the yolk gradually assumes a more viscid and tenaceous consistency, and a deeper and deeper tint, until it presents the rich orange colour characteristic of the mature ovarian ovum.

If one of these ova be transversely divided after being hard-boiled, the cut surfaces of the yolk will present three concentric strata of different colours; the external one is of a pale straw colour, the middle one of a deeper yellow, and the internal one is again light-coloured, and surrounds a substance of a whitish colour and more fluid consistency, from which a canal surrounded by a similar substance is continued to the cicatricula. The central substance and continuous canal are composed of albuminous fluid containing white granules, similar to the colliquamentum of the cicatricula.

The primitive vesicle of the ovum around which the material of the yolk is accumulated, by no means grows with the growth of the ovum; it is not more than one-half larger in the largest ovarian ovum, than it was when the ovum exhibited its smallest dimensions, and when the vesicle formed its most considerable part. Throughout the whole of this period it is, however, the most important part of the ovarian ovum; forming the essential element of the cicatricula, and the centre from which all subsequent development radiates.

Purkingé, the discoverer of the 'germinative vesicle,' states that it is most easily detected in the ova of the common Fowl, when they have attained the size of from four to six lines. The vesicle is at this period lodged in a mam-

* This figure, and those numbered 133, 134, 135, 136, 138, 151, 153, 163, 182, are copied from the plates of the second edition of Carus's 'Vergleichenden Zootomie.'

millary pile (*cumulus*) of white granular substance, which is surrounded by a whitish zone, and is continuous with the granular stratum applied to the internal surface of the membrana vitelli, but not adherent to that membrane.

The common envelope of the germinal vesicle, cicratricula, and yolk, is called the *membrana vitelli*. It is extremely delicate and transparent, without any perceptible organization, and forms an entire or shut sac. It is at first scarcely distinguishable from the stratum of granules forming the periphery of the yolk, and at this period the germinal vesicle closely adheres to it. Subsequently, however, a separation is effected by an interposed stratum of granules. The external membranes of the ova are thick in proportion to the vitelline membrane, and can with difficulty be detached from without lacerating it.

The part of the ovary in which the ovum is lodged is termed the *calyx* (*a*, *d*, *fig.* 185). It consists of two membranes; the external one is highly vascular; the internal one is somewhat smooth and pellucid, and is beset with equidistant, minute, and apparently glandular bodies.

As the ovarian ovum advances to maturity, a pedicle is developed from which the calyx with its contained ovum depends, and which permits it to be brought in contact with the infundibular orifice of the oviduct (*e*, *fig.* 185).

The external vascular tunic of the calyx then becomes covered with a rich profusion of vascular twigs (*b*, *fig.* 185) distributed in a pectinated manner, and converging towards a white transverse line, called the *stigma* (*c*, *fig.* 185). This stigma begins to appear when the ova have attained the diameter of an inch, in the form of a whitish streak, which continues to increase in breadth, and the membranes at that part to be thinned by absorption until they readily yield, and are rent by the compressing force of the infundibular opening of the oviduct, when the ovarian ovum escapes, and is received into the efferent passage.

The membrana vitelli is at this period sufficiently strong and ductile to permit the ovum being compressed into an elliptical form to facilitate its passage through the contracted part of the oviduct (*f*), but during this process Purkingé conjectures that the germinal vesicle of the cicatricula is ruptured and its pellucid contents diffused. It is certain at least that it can no longer be detected either in the cicatricula of the ovum of the oviduct, or in that of the excluded egg. The further changes which take place in the generative product, now no longer forming a part of the maternal system, will be described in the article Generation; and we resume the consideration of the female organs.

The calyx of the ovum, when emptied of its contents (*d*, *fig.* 185) collapses, shrinks, and is ultimately absorbed, not forming a permanent *corpus luteum*, as in Mammalia.

In Birds that have but few young at a brood, as the Eagles or Doves, the number of enlarged yolks is correspondingly small; but in the more prolific species, as the Common Fowl, they are more numerous. The number of young produced may be, by this means, in some degree inferred, if the female of a rare species happen to be killed during the breeding season.

The oviduct commences by the infundibular orifice, where its parietes are very thin; as it descends, these increase in thickness, and the efferent tube gradually acquires the texture and form of an intestine. Like this, it is attached to and supported by a duplicature of peritoneum called the *mesometrium*, but which also includes muscular fibres, to be presently described.

The oviduct in the quiescent state is generally straight, but at the period of sexual excitement it is augmented in length as well as capacity, and describes three principal convolutions before reaching the cloaca. The lining membrane presents a different character in different parts of the oviduct; at the infundibular extremity it is something like the mucous coat of the intestine, then it becomes rugous, and afterwards, at the part where the egg is detained and the chorion calcified, it presents a number of long close-set villi (*k*, *fig.* 185). This part is by some anatomists termed the uterus, but by a loose analogy, as the ovum is developed out of the body of the parent. The rest of the canal, which, *pari modo*, is termed vagina, opens into the urethro-sexual segment of the cloaca, anterior to the termination of the left ureter, and its termination (*f*, *fig.* 164, 176) is provided with a sphincter.

The mesometry (*m*, *fig.* 185) differs most from the mesentery when the female organs are in full sexual action. It presents at that period a true muscular structure. It is divided into two parts, one superior, the other inferior. The inferior mesometry has its point of attachment at the lower part of the uterine portion of the oviduct, and forms a somewhat dense and cruciform plexus of muscular fibres radiating from that part. The transverse fasciculi are spread out on either side and around the uterus. The lower fasciculus surrounds the vagina more laxly, and contributes to the expulsion of the ovum. The upper fasciculus spreads out like a fan upon the oviduct from its insertion into the uterine portion to the commencement of the infundibulum.

The superior mesometry commences by a firm elastic ligament, which is attached to the root of the penultimate rib of the left side, whence the muscular fibres are continued to the upper part of the oviduct, upon which they form a delicate muscular tunic, whose fibres embrace the oviduct for the most part in the transverse or circular direction, except at the infundibular aperture, where they affect the longitudinal direction, which enables them to dilate that orifice. Longitudinal muscular fibres begin again to be distinctly seen in the uterine portion of the oviduct, whence they are continued along the so-called vagina. An internal stratum of circular fibres is also situated immediately behind the calcifying membrane of the uterus. In the vagina the circular fibres are concentrated at its termination to form the sphincter above mentioned.*

The clitoris in the Ostrich is continued from the anterior margin of the preputial cavity of the cloaca, and is grooved like the penis of the male; it has also the same muscles inserted in it. A corresponding projection, as before observed, is met with in those birds of which the males have a well developed intromittent organ.

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(Richard Owen.)

* Purkinjé, Symbolæ ad Ovi Avium Historiam, 4to. 10. fig. 19.

AXILLA (surgical anatomy)—(Fr. *Aisselle*, Ger. *Achselgrube.*) Syn. *region axillaire*, Velp. is the Latin name for the armpit, and is used by anatomists to designate an important region situated between the upper extremity and the thorax.

The axilla in man is the seat of so many diseases and accidents; it contains so large a number of nerves, arteries, and lymphatic glands; and is so frequently interested in surgical operations, that a pretty full description of it is allowable on the present occasion.

When the arm is separated a little from the side, we observe, in the angle between them, a hollow space, which, in the adult, is always covered with hair. This is, in popular language, the armpit; but to the anatomist the term *axilla* conveys a very different notion. By him it is understood to mean a large region, *bounded* anteriorly by the greater and lesser pectoral muscles, posteriorly by the subscapular, the teres major, and a part of the latissimus dorsi, and internally by the ribs, the intercostal muscles, and the serratus magnus. It presents a basis below, formed of skin and fascia, and an apex above, which opens into the cervical region between the clavicle, scapula, and first rib. Its walls form, therefore, a kind of triangular pyramid, very unequal in their extent, very irregular, and continually undergoing alterations in size and shape. Its height is greater in the male than in the female, but its other dimensions are nearly equal. It is to be found in all animals which have an upper extremity, and its uses are subservient to the motions of that limb.

In the following description the adult male axilla is always supposed to be meant unless otherwise specified.

When the arm is raised to the horizontal position, we see the floor of this region, the base of our pyramid. This floor is triangular, having its truncated apex at the humerus, its base at the side of the thorax, and its sides formed by the folds of the axilla, that is, the great pectoral in front, the teres major and latissimus behind. It is concave, the concavity looking downwards and outwards. The skin is fine, covered with hair at its upper part from the time of puberty, and secreting, by numerous follicles, a fluid of a peculiar odour.

By raising the elbow higher than the head we convert the concave into a convex, the folds of the axilla are removed, the skin made tense, and the head of the humerus by descending is made to touch the floor of this region. Pressing the arm close to the side lowers the floor, shortens the margins, and relaxes all the parts composing the axilla. When the elbow is drawn a few inches from the side, the axillary artery and nerves may be felt along the humerus, and the head of this bone may be distinguished. In searching for disease in the axilla the arm must be placed in all these positions, but we are most likely to detect any abnormal condition of the parts when the elbow is drawn a few inches from the side, and supported without any effort of the patient.

Immediately under the skin we find some cellular substance, containing a small quantity of fat; and next a fascia of considerable thickness, which gradually loses itself on the side of the thorax, in the general superficial fascia of the trunk. It will be found extremely variable in different subjects, according to the *embonpoint* of the individual, sometimes loaded with fat, at other times thin, firm, and somewhat aponeurotic, with its principal bands stretched across from the anterior to the posterior wall of the axilla. In raising it, layer after layer may be removed, until it opens up into that extremely lax cellular tissue which attaches itself to the walls of the axilla, loosely supporting glands, vessels, and nerves, and permitting all the motions of which this part is capable. It is obviously cellular membrane. When enlarged glands, or abscesses, or tumours of any kind, form under it, it readily yields, and stretches before the distending force, never exerting any painful pressure on them. The cellular tissue under it is very loose. Numerous vessels ramify through it which are chiefly derived from the thoracica alaris artery. These vessels are occasionally ruptured, when extensive ecchymoses ensue. Matter formed here passes easily from one part to another, and gives rise to obstinate sinuses, not easily remedied on account of their length and tortuous course.

On carefully removing the dense cellular membrane of the floor, and that more loose tissue which it conceals, the edges of the axillary folds will be seen. Close to the anterior of them we observe the *thoracica longior* artery, with its accompanying veins and several lymphatic glands, and, under cover of the posterior, the subscapular vessels and nerves; whilst a great bundle of arteries, veins, and nerves, with the biceps and coraco-brachialis muscles, stretch along the humerus. To this view of the parts the operating surgeon will look with peculiar interest. It is from below that we generally operate on the axilla, and the three sets of vessels just now mentioned constitute the most important subjects for consideration when the scalpel is to be used. It is obvious that free incisions may be practised in the centre of this space or upon its thoracic side, but that all its other boundaries are beset with dangers.

To follow up the anatomy of this region with advantage, each of its walls must be examined in detail. The *anterior* wall consists of the pectoralis major and minor muscles. The *pectoralis major* is a large flat muscle, of a triangular shape, extending over the front of the thorax, from the clavicle and sternum to the humerus.

The origin of this muscle is curved, its convexity being directed upwards and inwards; this may be called its base. The insertion or apex is outwards and downwards. One surface looks outwards and forwards, the other backwards and inwards. The inferior margin extends from the seventh rib to the humerus and is nearly horizontal, folded on itself and free. The outer edge is nearly vertical, at first about an inch distant from the deltoid, but soon coming into contact with it, and so continuing to its insertion.

The triangular space between the deltoid and pectoral may be seen even in the living person when the shoulders are shrugged up, especially if the individual be thin. It is in this situation that the axillary artery commences, and might be cut down upon without dividing any muscular fibres except those of the platysma; it is however protected by the costocoracoid ligament, and by the edge of the pectoral muscle. In this interval we see the *cephalic vein* and a small artery, the *thoracica humeraria*, which is the descending branch of the thoracica acromialis. The cephalic vein is derived from a plexus on the outer and back part of the hand. After various communications in its superficial course it gets between the deltoid and pectoral muscles, and on arriving at the triangular interval above mentioned, it dips in under the edge of the great pectoral and just above the lesser, to empty itself into the axillary vein.

When the pectoralis major has been raised, we bring into view a stratum of cellular tissue, in which several branches of the thoracica suprema artery and some nervous filaments ramify before they enter the muscles. Underneath this tissue lies the pectoralis minor, still concealing the cavity of the axilla.

The posterior surface of the great pectoral is not nearly so extensive as the anterior; its fibres arise from the cartilages of the ribs, and, therefore, the extreme limit of the axilla in front is not to be estimated by the superficial dimensions of the muscle. A line drawn obliquely downwards and outwards, beginning one inch outside the sterno-clavicular articulation, and ending an inch outside the nipple, will nearly mark the junction of the anterior and internal walls.

This muscle is sometimes torn across by external violence. We have seen this occasioned by the passage of a railway carriage over it, and marked by a deep depression, but without any laceration of the integuments.

The *pectoralis minor* is shaped like the major, but it is considerably smaller. Its base is applied to the ribs, its apex to the coracoid process of the scapula. One surface is turned outwards and forwards to the greater pectoral, the other back to the axilla. Attached on the one hand to the upper edge and the external surface of the third, fourth, and fifth, and sometimes the second, true ribs, near their cartilages, by so many distinct slips, (hence its occasional name *serratus minor anticus*,) and an aponeurosis which covers the intercostal muscles, it terminates in a flat tendon which is inserted into the inner border of the coracoid process near its apex. In this situation it is intimately connected with the coraco-brachialis and short head of the biceps, sometimes sending fibres to be continuous with the triangular or coraco-acromial ligament, and in some rare instances the entire tendon runs across the coracoid process, and through this ligament to join the capsular ligament of the shoulder-joint. The tendon is about an inch broad; very short on the posterior surface, longer on the anterior, and longer still at the lower edge. The surface now exposed was covered by cellular tissue, and concealed by the pectoralis major every where except a small part of its lowest digitation, which is generally to be seen below it, in contact with the integuments.

The upper edge of this muscle is nearly horizontal, and placed about an inch below the clavicle. In the space between, when some fat is carefully removed, and some absorbent glands, we see the axillary artery running downwards and outwards, internal and anterior to which is the axillary vein, and behind it the nerves. The cephalic vein is observed passing upwards and inwards from the edge of the deltoid muscle to the axillary vein, and the thoracica suprema artery standing forwards from the axillary artery and resting on this edge of the pectoral. The thoracica acromialis artery runs in this space out towards the acromion process, and is often a branch of the suprema. Here, too, we see the lower surface of the subclavius muscle, turned forwards, and covered by a pretty strong fascia which terminates in the costo-coracoid ligament.

The *costo-coracoid* ligament is very thin, but strong. It extends from the cartilage of the first rib, just below the origin of the subclavius muscle, to the coracoid process of the scapula, in an arch across the vessels and nerves. It is concave inferiorly, and appears to be only the thickened edge of the fascia which covers the subclavius and descends a little below that muscle. This view of its true mode of formation is favoured by the fact that it has an attachment also to the clavicle, and consequently may be called *costo-cleido-coracoid*. The name *ligamentum bicorne* is sometimes applied to indicate its horn-shaped extremities; Blandin denominates it *fascia clavicularis*, and Gerdy, *ligament suspenseur de l'aisselle*. As a ligament it has little power, but as an aponeurosis it protects the vessels, and sends down a thin process upon them.

Below the lesser pectoral the vessels and nerves again come into view, and the thoracica longior or external mammary artery is seen passing downwards and forwards along its lower edge. For a fuller description of the preceding muscles, see Thorax, Muscles of the.

The *inner wall* of the axilla exhibits the ribs, intercostal muscles, and serratus magnus, with some vessels and nerves. One of these last is remarkable for its length and vertical direction; it lies on the serratus magnus, and appears as if flattened against the side of the thorax. It arises generally by two branches from the back of the anterior division of the fifth and sixth cervical nerves (counting eight in the neck). It communicates with the phrenic, descends behind the brachial plexus, under the clavicle and trapezius, appears upon the serratus magnus, on which it runs a great distance and enters its lowest division by many filaments. It is classed among the respiratory nerves by Sir Charles Bell, by whom it has been named the inferior external respiratory nerve of the trunk, its function being, according to his views, to associate the muscle to which it is distributed with the general respiratory movements. It was known to antecedent anatomists as the *posterior thoracic* branch of the brachial plexus.*

Crossing the axilla from the thorax to the arm, we see two nerves, frequently called *nerves of Wrisberg*. They are the external branches, or *costo-humeral*, of the second and third intercostal nerves. They pierce the external layer of intercostal muscles opposite the origin of the serratus magnus, between the second and third and the third and fourth ribs, and pass out obliquely to the arm, where they are lost in the integuments on the inner and back part of the arm and elbow. The superior of them is the larger.

The great vessels and nerves are seen passing from the first rib to the lower border of the teres major muscle, forming an arch whose concavity is downwards. By raising the arm to the horizontal position we obliterate the arch, and by supinating the hand strongly we bring them more into view. In the upper third of this curve the order of the parts, proceeding outwards, is, the axillary vein, axillary artery, and plexus of nerves. In the middle the vein is situated as before, and then the nerves surrounding and hiding the artery; and in the inferior third we first meet the vein, then the nerves, and lastly the artery.

The axillary vein is about three inches in length, commencing a little above the edge of the teres major; thence it runs upwards, inwards, and forwards to the second rib, which it touches, as also some fibres of the serratus magnus there arising; next it gets on the first intercostal muscles, after which it becomes the subclavian vein, crosses over the first rib, under the clavicle, before the scalenus anticus muscle, and then enters the thorax. It is formed by the confluence of three veins, viz. the *basilic* and the two *venæ comites* which convey their fluid from the fore-arm, and it is afterwards enlarged by the accession of those veins which accompany, usually in pairs, the subscapular, the thoracic, and the circumflex arteries. It also receives the *cephalic* a little higher up, as before described.

The *axillary artery* traverses this region from above downwards in a course doubly oblique, from within outwards, and from before backwards; at its upper part it rests on the chest separated by the serratus magnus muscle, and lies close under the anterior wall of the axilla, whilst below it rests on the subscapularis muscle (posterior wall), and is very near the arm. Its complicated relations with the nerves, veins, glands, &c. come more properly under consideration in the next article (Axillary Artery), to which we refer.

* One or two cases of paralysis of the serratus magnus muscle from injury to this nerve have been recorded. Velpeau mentions one, which resulted from a blow inflicted on the inner wall of the axilla: a permanent projection of the posterior edge of the scapula backwards, and inability to bring that bone into close apposition with the thorax, were the signs on which he founded his diagnosis. (See Cyclop. of Pract. Med. art. Paralysis.)—Ed.

It is plain from this view of the parts that a wound in the axilla, near the clavicle, might penetrate both the artery and vein, and be followed by aneurismal varix, but that no such consequence could follow a puncture of these vessels lower down. We see too that there would be much difficulty in compressing the axillary artery through the anterior wall of the axilla, (formed as it is of the two pectorals,) except in the triangular interval between the great pectoral and deltoid muscles close to the clavicle, and that the subclavius muscle and the ligamentum bicorne would bear off pressure even there to a great extent. In this place the vein and artery lie closer to each other than they do above the clavicle, a circumstance to be remembered in attempting to command the circulation of the limb. Collections of pus are often met with in the cellular tissue under the great pectoral muscle. In children they will frequently be found to have been occasioned by laceration which the tissue has suffered in the act of raising them up by the arm. These abscesses elevate the muscle considerably, and do not always point in the lower part of the axilla as might be expected. They approach the surface directly in front in some cases. But if an early opening were not made, it is probable they would oftener extend themselves all through the axilla.

The *nerves* in the axilla are large, numerous, and complicated. The principal ones are in a bundle, at first behind the axillary artery and then surrounding it. They arise in the cervical region, interlace in a remarkable way to form the axillary or brachial plexus, give off some branches in the neck, and on reaching the axilla separate to supply the arm, forearm, and hand. (For a particular description of this plexus we refer to the article Cervical Nerves.) The nerves we meet with in the axilla, besides the costo-humeral, are, *three thoracic* branches, *three subscapular*, and six others of much greater size, viz. the *external cutaneous*, *median*, *internal cutaneous*, *ulnar*, *musculo-spiral*, and *circumflex*.

The *thoracic* branches are most commonly three in number; the *anterior*, arising from the seventh cervical, runs in front of the great vessels and is lost in the pectoralis major and pectoralis minor muscles; the *middle*, very small, passes under the vessels and is lost in the lesser pectoral; the *posterior*, the largest, is the *respiratory*, and has been already described.

The *subscapular* branches are also three in number generally; they come from different points at the upper and back part of the plexus: the smallest quickly enters the subscapular muscle: the other two sometimes arise by a common trunk, or one of them comes from the circumflex, both run along with the subscapular artery, the larger pierces the teres major and is lost in the latissimus dorsi, the smaller is distributed to the subscapularis, teres major and teres minor.

The *external cutaneous*, or *perforans Casserii*, comes from the external part of the plexus, chiefly from the fifth and sixth cervical branches, and leaves the axilla by running downwards and outwards. It is superficial and external to the axillary artery.

The *median* arises from the front of the plexus by two roots, one of which is placed on each side of the artery; they soon unite, the nerve then lies on the artery, and inclining a little outwards escapes from the axilla, being destined principally for the hand.

The *internal cutaneous* issues from the internal and inferior part of the plexus, lies very superficially along the inner side of the artery, and quits the axilla where the basilic vein is entering.

The *ulnar*, arising from the internal and posterior part of the plexus, inclines backwards, separating itself slowly from the inner side of the artery.

The *musculo-spiral* arises still farther back, and is concealed from view by the other nerves.

The *circumflex* nerve arises above and behind all the others, and completely concealed by them; it descends before the subscapular muscle for a little, then turns backwards and outwards, close to the capsular ligament of the shoulder-joint, and in company with the posterior circumflex artery; then it appears on the outside of the neck of the humerus, between the long head of the triceps, the bone, and the teres major and minor muscles, and soon enters the deltoid in two branches. The situation of this nerve accounts for the paralysis of the deltoid muscle which sometimes follows dislocation of the head of the humerus into the axilla.

Lymphatic glands are found in great numbers in the axilla; some are scattered over the internal wall, but there the majority of them will be found in a chain along with the external mammary, or thoracica longior artery. On the posterior wall they form a chain also, in the course of the subscapular vessels. Some will be seen above the lesser pectoral, and several along the axillary vein. Round this last vein we see numerous lymphatic vessels twining.

When the clavicle has been detached from its connexion with the trunk, and along with the scapula raised from the side, the *serratus magnus* may be seen to form the greater part of the internal wall, but extending far below it. This is a flat irregularly quadrilateral muscle; one surface of it is in contact with the side of the thorax; the other, looking externally, touches the subscapular muscle, the axillary vessels and nerves, the two pectorals, the latissimus dorsi, and the integuments. The anterior edge presents a convexity forwards, and consists of digitations or fleshy slips which arise from the first eight or nine ribs. The fibres all run back to the posterior margin of the scapula, along the whole of which they are inserted.

The thoracic surface of the muscle, which may be seen by cutting through the trapezius and rhomboid muscles, and pulling out the base of the scapula from the ribs, rests on loose cellular tissue, which connects it with the ribs, intercostal muscles, and serratus posticus superior.

The *posterior wall* of the axilla is formed by the *subscapular* muscle, the *teres major* and the *latissimus dorsi*, to which the long head of the triceps may be added. Along the inferior margin of the subscapular muscle, the subscapular artery runs. This is a vessel of considerable size, and deserves the attention of the surgeon. It arises from the axillary artery at the tendon of the subscapular muscle, and passes all along the inferior or anterior edge of this muscle to the inferior angle of the scapula, where it terminates by branches which supply the muscles connected with that point. The teres major is a long, flat muscle, strap-shaped, one inch and a half or two inches in breadth, extending from the inferior angle of the scapula, to the posterior margin of the bicipital groove of the humerus. Its lower edge is in part covered by the latissimus dorsi and then by the integuments, and forms, principally, the posterior fold of the axilla. The posterior surface is covered by the latissimus, nearer the arm by the integuments, and then by the long head of the triceps and the humerus. Its anterior surface corresponds to the subscapular, latissimus, coraco-brachialis, biceps, and the axillary vessels and nerves.

The latissimus dorsi forms a very small part of the axilla; we see it passing over the inferior angle of the scapula and twisting round the teres major, so that its posterior surface becomes anterior, and the tendon in which it ends gets internal to that of the teres. Its edge does not go quite so low as that of the teres major, but, except there, it prevents that muscle from touching the axillary vessels. It is sometimes connected to the great pectoral by a fleshy slip which passes across the axilla.

The axilla has all the conditions which expose a part to frequent disease; a position which puts it in the way of many external injuries; an important joint closely related to it; bones, liable to fracture; arteries, veins, and nerves of great size; numerous lymphatic glands, connected with the most delicate parts of the body, lying in it; and then a quantity of cellular tissue, loose, vascular, and constantly undergoing alterations.

To the observations made on these points in the course of the present article, we shall now make a few additions.

Wounds penetrating into the axilla endanger the nerves, artery, and vein, if inflicted near the humerus below, or close to the clavicle above. In the latter situation, as mentioned before, they may give rise to aneurismal varix. At the lower margin of the anterior wall the external mammary artery may be injured, and along the inferior border of the posterior wall the subscapular vessels lie exposed.

The shoulder-joint is more liable to dislocation than any other in the body, and in most cases the head of the humerus comes into the axilla. The great vessels and nerves are displaced inwards, the circumflex vessels and nerve often torn. The head of the humerus lies just below the subscapular muscle, and forms a tumour in the axilla easily felt from below. (See Shoulder, Articulations of the.)

The neck of the humerus is often broken above the insertion of the arm-pit muscles. The lower fragment is drawn inwards by them and upwards by the deltoid, whilst the supraspinatus directs the upper fragment out. In this state of things the rough extremity of the lower piece irritates, perhaps lacerates the vessels and nerves, and if not properly managed leaves a permanent osseous tumour in the axilla.

Collections of matter are very frequently met with in the axilla. These occur either about inflamed glands, or in the cellular tissue connected with these glands, or they may have found their way into this region, their focus being somewhere else. The abundance of cellular membrane here, its vascularity, its incessant movements, and the dragging and stretching to which it is exposed, render it very liable to formations of pus. Irritation of the delicate integuments may occasion them, and they may be formed in the neck and pass into this region through the opening at its apex. The looseness of the texture is such as to allow suppurations to go on to a great extent, whilst the movement of the walls predisposes to their termination in sinuses.

The absorbent glands, however, are the organs which most frequently take on disease in this place. These may become inflamed and enlarged from sympathy with disease or injury in any part of the corresponding limb, the back, the surface of the thorax, or the upper part of the abdomen. When inflamed, they often run on to suppuration, or resolution may follow on the removal of the exciting cause. Slight lesions of the skin of the parts mentioned may determine the formation of abscesses, as a scratch on the finger, a blister on the chest, &c. Paronychia is not an unusual exciting cause.

Formidable inflammations of these glands, often attended with fatal consequences, follow the absorption of poisons. The cases most familiar to us in this country arise from wounds received in dissecting. The glands seem to arrest the poison in its progress to the circulation. They become excited and congested. The cellular tissue surrounding, imbedding and partly forming them, inflames; a puffy swelling marks the effusion of serum into the cellular membrane, which may or may not be followed by suppuration.

The glands frequently take on the disease under which the neighbouring mamma labours, as cancer, fungus hæmatodes, &c. These must be removed if the breast be amputated. They are generally in the course of the external mammary artery, and no other vessel is interested in their removal, yet the looseness of the tissue in which they lie renders it unsafe to cut the little vessels derived from this inconsiderable artery. Surgeons usually twist or tear away the glands, or else apply a ligature to the vessel before they cut it.

In almost every disease in the axilla the arm swells on account of the pressure exerted on the absorbents and veins.

For the BIBLIOGRAPHY see that of ANATOMY (INTRODUCTION).

(Charles Benson.)

AXILLARY ARTERY *(arteria axillaris)*. This artery, which is the continuation of the subclavian trunk, commences at the outer border of the first rib, beneath the lower margin of the subclavius muscle: lying at first on the external surface of the superior part of the thorax, it traverses the axillary space, applies itself to the internal side of the upper extremity, and terminates at the lower edge of the tendon of the teres major muscle. The average length of this vessel is about six inches: when the arm hangs by the side it describes a curve in its course, the concavity of which is downwards and inwards, but it is brought to a nearly horizontal right line by raising the arm to a right angle with the trunk, and it may be made to describe a curve, the concavity of which is turned upwards, by raising the arm to the greatest possible extent of elevation.

The depth of this artery from the surface is greatest at its commencement, whence to its termination it gradually becomes more superficial.

Relations.—Anteriorly the axillary artery is covered by the following parts; on first emerging from under the margin of the subclavius muscle, it is covered by the costo-coracoid ligament, beneath which the anterior thoracic nerves coming from the brachial plexus cross it in their course to the pectoral muscles, the vessel then passes under the pectoralis minor muscle, from the lower edge of which to its termination the coraco-brachialis lies in front of it. Posteriorly it rests at its commencement on the first intercostal muscle, then, with the interposition of a considerable quantity of cellular tissue, on the first digitation of the serratus magnus, which separates it from the external surface of the second rib, it next crosses the tendon of the subscapularis muscle, from the lower edge of which to its termination it lies on the anterior surface of the tendon of the teres major. Externally it is bounded by the lowest cord of the brachial plexus, until it arrives at the superior edge of the subscapularis, and for the remaining part of its course by the commencement of the external cutaneous nerve. Internally it is bounded by the axillary vein, which is in contact with it in the whole of its course, except while crossing the subscapularis, where the internal root of the median and the ulnar nerve separate the vein from the artery.

The lesser pectoral muscle, in crossing the axilla at the lower part of the upper third of that region, divides the axillary artery into three stages. The first extends from the clavicle to the upper edge of the lesser pectoral; in this stage the most important relation which the artery has, is to the vein, which lies upon its inner side and upon a plane anterior to it, so that in a state of distension the vein would overlap the artery. All the nerves are behind and external to it. In the second stage, which is that concealed by the lesser pectoral, the vein, still on the thoracic side and more anterior, is separated from the artery by the nerves, which, forming the axillary plexus, are so closely applied to it, behind and on each side, as to form, as Velpeau remarks, a complete nervous sheath. In the third stage, which is below the lesser pectoral and in immediate connexion with the subscapularis muscle, the artery is still in the midst of nerves, having on each side a root of the median, together with the external cutaneous nerve on the outside and the internal cutaneous and ulnar on the inside, the circumflex and musculo-spiral being posterior to it. In this stage the vein is internal and superficial to the artery, but separated from it by the nerves which lie on its internal side.

A ligature cannot be placed on the axillary artery in any stage of its course without endangering parts of great importance; in the second stage, however, the connexion of the artery with the axillary plexus is so intimate as completely to preclude the possibility of tying it there without incurring the greatest risk of serious injury. Hence there are but two situations in which it can be deemed prudent to expose this artery. Of these the operation in the third stage may be accomplished with greater facility, because the artery is here much more superficial, and although its relations are numerous, and in some degree complicated, they admit of being separated from the artery to such a distance as will guard them from injury. To tie the artery in the first stage, however, is much more difficult, chiefly in consequence of the great depth at which it lies, the necessity there is for cutting through large muscles, and the almost certainty of troublesome and unavoidable venous hæmorrhage. The principal part which the surgeon has to avoid in applying the ligature needle is the vein.

Branches.—The axillary artery usually gives off six branches, viz.; 1. the acromial; 2. the superior thoracic; 3. the inferior or long thoracic or external mammary; 4. the subscapular; 5. the posterior circumflex; 6. the anterior circumflex.

1. *The acromial artery (thoracica acromialis)* arises from the anterior side of the axillary artery above the edge of the lesser pectoral muscle, and after having given off some branches to the subclavius, serratus magnus, and first intercostal, it passes obliquely downwards and outwards, piercing the expansion of the costo-coracoid ligament, and arrives at the posterior surface of the deltoid muscle, where it divides into a superior and an inferior branch.

The superior branch mounts by a tortuous course towards the clavicle; this branch, which is more particularly designated by the term *acromial*, after having given off one or more branches to the deltoid muscle and the integuments, runs along the anterior border of the clavicle, behind the origin of the deltoid, until it arrives at the acromial end of that bone, where it is expended in a number of branches which go to supply the scapulo-clavicular and scapulo-humeral articulations, and also the supra-spinatus and deltoid muscles. This artery anastomoses with the supra-scapular and posterior circumflex in the vicinity of the acromion process. The inferior or cephalic branch descends in company with the cephalic vein in the cellular interval between the deltoid and pectoralis major muscles, and is distributed to these muscles and the integuments.

2. *The superior thoracic* (*thoracica suprema*, Sœm.) is very irregular as to the place of its origin, coming as frequently from the acromial as from the trunk of the axillary; it passes obliquely forwards between the greater and lesser pectoral muscles, and divides into several branches, which are distributed to these two muscles, the integuments, and more deeply to the serratus magnus and the two or three superior intercostal muscles, anastomosing with the intercostal and internal mammary arteries.

3. *The inferior thoracic* (*thoracica longior* or *mammaria externa*) is subject to the same variety of origin as the superior thoracic; it sometimes arises from the subscapular. This artery descends on the surface of the serratus magnus muscle along the inferior border of the pectoralis major; its branches are distributed to the glands and cellular tissue of the axilla, to the serratus magnus, and pectoralis major and minor, and the intercostal muscles; it also supplies the mammary gland and the integuments; it anastomoses with the intercostal, internal mammary, superior thoracic, and subscapular arteries.

Sœmmerring describes a fourth thoracic artery, under the name of *alaris sive axillaris glandulosa*,* which is distributed principally to the axillary lympathic glands; this artery is very irregular in its origin, sometimes coming from the trunk of the axillary artery, and as often arising from the thoracica longior or the subscapularis. Instead of a single artery going to the glands of the axilla, these parts are more usually supplied by several small twigs which arise from the arteries in their vicinity.

4. *The subscapular artery* is generally the largest branch of the axillary; it arises at the lower edge of the subscapularis muscle, lying at its origin behind the brachial plexus; it gives three or four branches to the glands and cellular tissue of the axilla and to the subscapularis muscle, after which it divides into two branches, one inferior, the smaller, the other, larger, called the external scapular. The inferior branch descends along the inferior border of the subscapularis muscle and the inferior costa of the scapula between the latissimus dorsi and the serratus magnus, to which muscles, the teres major, and the integuments it is finally distributed, anastomosing with the posterior scapular artery at the inferior angle of the scapula. The external branch, *circumflexus scapulæ* of Sœmmering, passes backwards through a triangular space formed by the subscapularis above, the teres major inferiorly, and the tendon of the long head of the triceps externally, and after having given several branches to these muscles, it divides into two branches, a superficial and a deep-seated; the superficial branch is distributed to the teres major, teres minor, infra-spinatus, latissimus dorsi, and the integuments; the deep-seated branch winds round the neck of the scapula under the teres major, and entering the fossa infra-spinata, supplies the infra-spinatus muscle, the scapula, and the scapulo-humeral articulation. This branch anastomoses freely with the branch of the supra-scapular, which descends under the root of the acromion process.

5. *The posterior circumflex*, next to the subscapular, is the largest branch of the axillary artery, from the posterior side of which it arises: frequently it comes from the infra-scapular. It passes backwards through a quadrilateral space, bounded in front by the neck of the humerus, behind by the long head of the triceps, above by the subscapularis, and below by the teres major; coursing round the neck of the humerus, it passes below the inferior edge of the teres minor, and attaching itself to the under surface of the deltoid, is principally distributed to that muscle, giving branches in its course to the capsular ligament of the shoulder-joint, the subscapularis, teres major and minor, infraspinatus, and triceps; it anastomoses with the supra-scapular and acromial thoracic by branches which it sends to the acromion, and with the anterior circumflex by the branches which it gives to the articulation of the shoulder.

6. *The anterior circumflex* is a very small vessel, arising either from the axillary or the posterior circumflex; it passes forwards round the neck of the humerus under the coraco-brachialis and short head of the triceps, to both of which muscles it gives branches; arriving at the bicipital groove, it sends off several branches, some of which descend along that groove, and others spread over the surface of the head and neck of the humerus, supplying that part of the bone and the tendons which are inserted into its tuberosities; while the continuation of the vessel entering the bicipital groove ascends by the side of the tendon of the long head of the biceps, passes under the capsular ligament, to which and the other parts entering into the formation of the shoulder-joint it is ultimately distributed. This artery anastomoses with the posterior circumflex and ascending branches of the superior profunda of the brachial artery.

For the Bibliography see that of ANATOMY (INTRODUCTION) and of ARTERY.

(*J. Hart.*)

AZYGOS, (α, ζυγος, *jugum.*) The term *azygos* is applied by anatomical writers to certain parts of the human body, which, being situated in or near the mesial line, appear singly, and not symmetrically or in pairs: thus we read of the azygos process of the sphenoid bone, of the azygos uvulæ muscle, of the azygos artery, vein, &c. This term, however, (strictly speaking,) is seldom very correctly applied, for in the cases of the bony

* De Hum. Corp. Fab. t. v. p. 189.

process and muscle quoted, each is composed of parts that were originally double or symmetrical, which have coalesced in the middle line so completely as to appear single; as to the vessel, the description of which will form the subject of the present article, there is very frequently an analogous trunk, only somewhat smaller, on the opposite side of the spine.

Azygos vein, *Posterior thoracic*, *Prelumbo-thoracique*, *Vena sine pari*, *Azygos major*. This vein exists in the posterior part of the cavity of the thorax, on the right side of the bodies of the dorsal vertebræ; it serves to receive the blood from most of the intercostal spaces, from the phrenic, bronchial, and mediastinal veins, as also from the vertebræ and vertebral sinuses, and to convey it into the superior vena cava; it also establishes a communication between this last-named vessel and the inferior cava through some of its lumbar branches, and thus connects the veins of the upper and lower segments of the body, in the same manner as the internal mammary and epigastric, and several others of the thoracic aud abdominal arteries inosculate.

In the present article we shall consider not only the greater and lesser vena azygos, but also the principal branches which each receives —namely, the intercostal and bronchial veins. The right or great vena azygos presents many varieties as to the size and number of its branches, as well as in its exact origin; it usually commences very small opposite the first or second lumbar vertebra, on the upper extremity of the right psoas muscle from the confluence of several minute veins, which communicate with branches from the superior lumbar, capsular, renal, and spermatic veins, and thus indirectly with the abdominal cava; it not unfrequently, however, arises by a branch from the cava itself, in which case it appears even in this region as a vessel of considerable size. The abdominal portion of the vena azygos is but short, ascends obliquely inwards, crosses the right crus of the diaphragm, and enters the posterior mediastinum between the crura of this muscle in company with, and to the right side of the thoracic duct and aorta; it is here surrounded by so much cellular and adipose tissue as to be frequently very indistinct; it sometimes enters the chest along with the right splanchnic nerve through an opening in the right crus itself, or external to the latter, between the attachments of the diaphragm to the body and transverse process of the first lumbar vertebra. The thoracie portion of the vena azygos ascends along the right side of the vertebral column in front of the right intercostal arteries, and covered by the right pleura, to which it is closely connected, being, in fact, contained in the subserous cellular tissue; the aorta is to its left, and in the intervening adipose matter the thoracic duct is placed; the right splanchnic nerve is external to it or on its right side. Opposite to about the fourth dorsal vertebra the vein leaves the spine, increases very much in size, arches forwards and to the right, around and above the right pulmonary artery and bronchial tube, and opens into the back part of the superior vena cava, immediately above the reflection of the serous layer of the pericardium on that vessel. A small fold of the lining membrane of the azygos vein, a mere rudiment of a valve, exists at its junction with the cava; sometimes, however, this fold is well developed, it is even observed to be double. Similar folds or valves are occasionally found lower down in the vena azygos, but generally it is destitute of valves. The vena azygos has been seen by Cheselden to open into the vena cava within the pericardium close to the right auricle; it also occasionally opens into the cava at a point higher than that which has been stated as its regular termination, and it now and then joins the right or even the left vena innominata.

The vena azygos receives several veins; in the abdomen and in its passage through the diaphragm it is joined by one or two of the superior lumbars, and by small branches from the diaphragm; in the thorax it receives the intercostals; the seven or eight inferior intercostals of the right side enter it distinctly; the corresponding number of the left side sometimes join it in a similar manner, but most commonly they first unite into a trunk, called the left or minor azygos, of which we shall speak presently. The three or four superior intercostal veins of the right side unite into one or two branches which end in the convexity at the upper extremity of the azygos major, which also receives the right bronchial veins in the same situation, and at a lower point the œsophageal; the latter, like the arteries of the same name, are irregular in number and in situation.

The left vena azygos, *azygos minor*, *semi-azygos*, is smaller, but in other respects similar to the right; it commences by small branches from the superior left lumbar, capsular, and renal veins, which unite into a delicate vessel that sometimes communicates with the right azygos, and sometimes with the inferior cava; it then passes through the aortic opening in the diaphragm, or through or external to its left crus in company with the left splanchnic nerve, and ascends along the anterior and left side of the dorsal vertebræ as high as the seventh or eighth; it then crosses the spine behind the aorta, œsophagus, and thoracic duct, to join the right or great vena azygos. The azygos minor receives the six or seven inferior left intercostal veins, and as it is passing across the spine it is generally joined by a large descending branch which is formed by the confluence of some of the superior of these vessels; the azygos minor also receives the left bronchial veins as well as some branches from the diaphragm, œsophagus, and mediastinum. In some subjects this vein is wanting; in such cases the left intercostals join the proper azygos either individually, or by two or three uniting into a large branch.

The intercostal veins are eleven or twelve in number on each side; in their course and distribution they correspond to the intercostal arteries; they commence each by the union of small branches near the sternum, which anastomose with the internal mammary veins; they then accompany the intercostal arteries along the groove in the lower border of each rib; near the spine they increase in size, being joined by several veins from the exterior muscles of the spine, which pass through the internal part of each intercostal space along with the posterior branches of the intercostal arteries; in this situation also they receive veins from the vertebral canal, communicating with the vertebral sinuses on the posterior surface of the bodies of the vertebræ, and passing through the intervertebral holes along with the spinal nerves. All the intercostal veins communicate with each other over the heads of the ribs, either by many small or by a few larger branches; the veins of the opposite sides also communicate by transverse branches, so as to give to the anterior surface of the dorsal vertebræ, in a successful injection of the venous system, an appearance somewhat analogous to the vertebral sinuses on their posterior surface. The first intercostal vein of the right side generally ascends over the neck of the first rib, and over the first dorsal ganglion of the sympathetic nerve, and joins the subclavian vein or some of its deep cervical branches; the second intercostal frequently joins the first, and sometimes the third also terminates in a similar manner, but usually the fourth, third, and often the second open into the arch of the azygos by one or two branches: these superior intercostal veins always communicate with each other and with the azygos below, as well as with the subclavian above. The remaining intercostal veins of the right side enter the azygos separately, or two or three occasionally unite and end by a common opening; the inferior ascend, the middle take a transverse course, and the superior descend; near the spine they all anastomose freely with each other, so that the heads of the ribs support a chain or network of these vascular inosculations, as is well represented in Breschet's plates of the venous system.

The superior intercostal vein of the left side always joins the left subclavian or some of its large branches, the internal mammary in particular; it is usually a large vein, but it presents great varieties; in some it appears as a third vena azygos, and might be named the left *superior azygos;* in such cases it communicates below with the inferior azygos about the sixth dorsal vertebra and above with the left subclavian; in the intermediate space it receives the corresponding intercostal veins, also the œsophagæal, mediastinal, and left bronchial; this vein sometimes also communicates directly with the right azygos. The remaining left intercostal veins enter the lesser azygos, or if this vessel be absent, they cross the spine behind the œsophagus, aorta, and thoracic duct, and enter the great azygos separately, or two or three conjoined. The superior and inferior azygos veins of the left side are sometimes continuous, and enter the left subclavian, thus taking a parallel and very similar course to the vein on the right side, particularly when the latter opens so high as into either of the venæ innominatæ.

The bronchial veins arise in the cellular tissue of the lungs from the extremities of the bronchial arteries; as the branches unite into larger vessels, these are found to accompany very closely the divisions of the bronchial tube; they leave the root of each lung two or three in number; on the right side one joins the arch of the azygos or the superior vena cava, the others open into the azygos lower down, or into some of the mediastinal or intercostal branches. The left bronchial veins arise in a similar manner, escape from the root of the left lung, and open either into some of the superior intercostal veins, or into the superior or inferior azygos minor. In minute injections of the lungs these veins are found to inosculate with the capillary terminations of the pulmonary arteries. Both the right and left vena azygos receive numerous branches from the posterior mediastinum, from the coats of the aorta, pericardium, œsophagus, bronchial glands, trachea, &c. &c.; these veins pursue no regular course; they receive names either from the arteries they accompany, or from the organs whence they are derived; they require no particular description.

The vena azygos is the principal vein appertaining to the parietes of the chest; it not only serves to receive the several branches which have been mentioned, but also maintains numerous communications between different portions of the venous system, which must prove of essential service in case of obstruction to the circulation in any of the principal trunks: thus, its abdominal portion communicates either directly with the inferior vena cava, or indirectly through the medium of the lumbar, phrenic, renal, or spermatic veins, while its thoracic end joins the superior cava, and at the same time anastomoses on either side with the subclavian vein or some of its branches. On both sides of the thorax again it inosculates by its intercostal communications not only with the internal mammary, but also with the thoracic branches of the axillary veins, and along the vertebræ it communicates with the vertebral sinuses, opposite each foramen of conjunction. This vein, consequently, appears not only as one of the roots of the cava, but also as a loop or second channel between the two cavæ, which, in case of the obstruction of either, more particularly of the inferior, would convey the blood to the heart, and thus obviate any impediment to the venous circulation of the lower segment of the body. Cases have even occurred in which the inferior cava has been obstructed or nearly obliterated by the pressure of a tumour or of a diseased liver and in these this anastomosis, and indeed the whole vena azygos have been found greatly increased in size. The vena azygos appears moreover to have been formed as a convenient means for receiving numerous venous branches which could not reach any of the large vessel without some more complicated provision: thus the inferior intercostal veins could not join the inferior cava, where the latter is imbedded in the liver, without perforating the diaphragm; neither could the middle and superior intercostal, the mediastinal, and the bronchial veins arrive at the superior cava or at the right auricle of the heart without a much more complex disposition of all these parts than we observe.

For the BIBLIOGRAPHY see that of VENOUS SYSTEM.

(Robert Harrison.)

BACK, REGION OF THE (surgical anatomy). Under this denomination, which is of Saxon origin, it is intended to describe the posterior regions of the body situated between the head and the pelvis, including a *cervical*, a *dorsal*, and a *lumbar* region, varying in breadth in these different portions, and corresponding in length to that of the spine. The skeleton of this extensive region consists of the spinal column, and a portion of the ribs, and to the former of these it is chiefly indebted for its longitudinal curvatures. Thus we find it concave in the cervical and lumbar portions, convex in the dorsal. (See SPINE.)

In its whole course from the os occipitis to the base of the sacrum, we observe a central depression occasioned by the prominence of muscular masses on each side. In weak and emaciated subjects a rugged ridge takes the place of this depression; the ridge is the series of spinous processes which have little or no muscular covering, and are hid when the muscles on each side are much developed. At the junction of the cervical and dorsal portion, however, the ridge is scarcely ever obscured, because there the spines are very long and the muscles thin; and again, the depression at the top of the neck is only rendered deeper by emaciation.

The length of the *cervical region* is well defined by the external tuberosity of the os occipitis above, and by the prominent spine of the last cervical vertebra below. Its breadth, at the upper part, extends from one mastoid process to the other; in the middle it becomes narrower, and inferiorly it again spreads out almost to the acromio-clavicular articulations. Its length and breadth vary in different individuals. In general it is broader, proportionally, in the male than in the female, especially at the upper part, where, according to Gall, it may be considered a measure of amativeness. At the top of this region we see a remarkable depression, called the *suboccipital fossa*, or *cervical fossa*; its existence depends on the absence of a spinous process in the atlas, while the muscles on either side, chiefly the complexi, stand out boldly. In fat persons a quantity of adipose substance fills up this hollow and nearly obliterates it. The upper third of the neck, and in some persons much more, is covered with hair. This part is technically called *nucha*, a term of Arabian origin. Its common appellation is *nape* of the neck. (See *fig*. 2.)

The *dorsal region* corresponds in length to the twelve dorsal vertebræ, with their intervertebral substances, and in this dimension it is well defined, but its breadth is not so settled; anatomists bound it by the angles of the ribs on either side, while surgical writers extend it somewhat farther. This region is convex from above downwards, and from side to side also, if we overlook the slight central depression.

The *lumbar region* extends from the last dorsal vertebra to the base of the sacrum, and on each side to the outer margin of the sacro-lumbalis muscle. These bounderies can generally be seen and felt without difficulty. It is a little concave from above downwards, convex, or nearly plane, from side to side, with the central depression slightly marked.

Integuments.—The integuments of the back are every where strong and coarse. They are particularly so over the spinous processes, where an imperfectly marked raphè exists; they are also more fixed along that line than elsewhere, on account of the density of the cellular tissue which connects them to the supra-spinal ligament, and in many subjects the raphè is hairy.

The sensibility of the skin is much less on the posterior than on the anterior surface of the body; the nerves and vessels are not so numerous, nor is its organization so high. Hence its resistance to the action of vesicatories and rubefacients, which must be stronger, or applied for a longer period to produce the required effect. The skin is also very unyielding, so that collections of matter do not readily make their way to the surface, and if not opened early may spread under it extensively.

Subcutaneous cellular tissue.—On raising the integuments a layer of cellular substance is observed, not containing much fat. It is strong, coarse, and filamentous, and adheres to the skin more than to the muscles. In passing a seton in the neck we pinch it up with the skin, and transfix it without touching the muscles, which could not be wounded with impunity. Along the middle line this fascia is more connected to the deeper parts than it is on either side, and especially in the dorsal region.

This cellular tissue is frequently the seat of post-mortem congestions and effusions arising from the gravitation of the fluids to so dependent a position; hence we generally find it either very vascular or infiltrated with fluid, in a state quite resembling anasarca.

A very fine layer of cellular tissue, underneath this again, closely adheres to the muscular fibre, and a good deal of motion may take place between these two layers.

The arteries which supply the skin and fascia in the neck are branches of the occipital, the cervicalis profunda, and the transversalis colli, to which the vertebral and transversalis humeri may contribute a little. In the dorsal region the posterior scapular and the dorsal branches of the intercostals principally supply these parts; and in the lumbar region we have the posterior branches of the lumbar arteries. None of these approach the skin in their undivided state, so that superficial wounds here can never be followed by troublesome hæmorrhage. In the fascia we generally find a vein, described by Godman of Philadelphia under the name of the *dorsal azygos*. It arises at the lower part of the back by irregular roots, runs up single for some time along the middle line, and then divides into two branches, one of which pierces each trapezius, and enters into the transversalis colli vein. It is small and of little importance. The other veins are not of sufficient size to deserve particular notice; they are found in company with the arteries.

Nerves.—The nerves of this region are the posterior branches of all the spinal nerves. The cervical and brachial plexuses also send some filaments; but its nervous supply is, like its vascular, very scanty.

Lymphatics.—The lymphatics, too, are not so numerous as elsewhere. We trace them running to the cervical, axillary, and inguinal glands, according to their proximity to these. With the exception of two or three on the cervical portion of the trapezius, lymphatic glands are not met with here.

The back is peculiarly subject to anthrax in debilitated constitutions, and in some cases the tumour acquires great magnitude. It sometimes happens that several anthraxes occur in succession, until a large portion of the integuments and fascia is destroyed, and the patient sinks under the disease. Pressure is frequently the exciting cause. By pressure the vessels are so obstructed that the vitality of the part is impaired, and its organization is too low to enable it to recover from the deadening effects, especially if the constitution be previously injured. Here too we often meet with furunculi: they are most common in the nape of the neck. Fistulæ in the lumbar region, depending on diseased kidney, sometimes present themselves. There is no peculiarity in the cutaneous or other diseases to which it is liable in common with other regions.

BACK, MUSCLES OF THE.—The muscles of the back are very numerous and complex. There is much variety in their origins and insertions in different subjects, and in many cases it is not easy to decide with which of two adjoining muscles we are to connect certain bundles of fibres; a distinct impression, therefore, is not always obtained from an examination of the part, nor will a repetition of the dissection present us with the same view in another subject. Hence it happens that anatomists differ as to the number of muscles to be met with, some dividing into two or more muscles what others consider as one; this proves another source of difficulty. The names and the enumeration of them, as given by Albinus, we shall follow pretty closely: we esteem them the best on the whole, and they have the advantage of being generally adopted in these countries: viz. the *trapezius* or *cucullaris*, *latissmus dorsi*, *rhomboideus major*, *rhomboideus minor*, *levator anguli scapulæ*, *serratus posticus superior*, *serratus posticus inferior*, *splenius capitis*, *splenius colli*, *sacro-lumbalis*, *longissimus dorsi*, *spinalis dorsi*, *semi-spinalis dorsi*, *cervicalis descendens*, *transversalis colli*, *trachelo-mastoideus*, *complexus*, *spinalis colli*, *multifidus spinæ*, *inter-spinales*, *inter-transversales*, *rectus capitis posticus major*, *rectus capitis posticus minor*, *obliquus capitis inferior*, and *obliquus capitis superior*. These muscles are placed in pairs, one on each side of the median line; none of them can be said to be exactly in the middle. We shall examine them in the order they present themselves to us in dissecting.

We find these muscles disposed in *layers*, and each layer differing from the others in the shape or use of the pieces which compose it. Six such layers may be enumerated. The *first* consists of the trapezius and latissimus dorsi, muscles somewhat triangular in form, and destined to act principally on the upper extremity. The *second* consists of the rhomboidei and levator anguli scapulæ. These are quadrangular, approaching a square shape, and act on the scapulæ. The *third* layer is formed of the serrati, of similar shape, but acting on the ribs. The *fourth* consists of the splenii; these, more elongated than the last, rotate and erect the head and neck. The *fifth* layer is composed of very long muscles, acting chiefly as erectors of the spine and head, viz. the sacro-lumbalis, longissimus dorsi, spinalis, and semi-spinalis dorsi, cervicalis descendens, transversalis colli, trachelo-mastoideus and complexus. The *sixth* layer, again, is formed of short muscles, rotating and erecting the head or minute portions of the spinal column; these are the recti and obliqui of the head, the spinalis colli, inter-spinales, inter-transversales, and multifidus spinæ.

First layer.—The trapezius and latissimus dorsi, which form the *first layer*, almost completely conceal all the other muscles of this region, and in superficial extent are scarcely succeeded by any two muscles in the body.

The *trapezius* is thin, triangular, and very extensive. One of its surfaces is turned to the integuments, and covered by the superficial fascia, and by a fine layer of cellular tissue which closely adheres to it. The trapezius *arises* from the internal third of the superior oblique ridge of the os occipitis, from the ligamentum nuchæ, and from the spinous processes of the last cervical and of all the dorsal vertebræ. The superior fibres run downwards, outwards, and a little forwards, the middle transversely, and the inferior upwards and outwards; all converge, and are *inserted* into the external third of the posterior border of the clavicle, the acromio-clavicular ligament, the acromion process, the upper edge of the spine of the scapula, and the tubercle which terminates this spine at the base.

The origin of this muscle is by tendinous fibres which are from half an inch to an inch long in the occipital portion; in the cervical they are very short until we come down to the sixth cervical vertebra, where they begin to lengthen; at the first dorsal they are an inch and a half in length, again they diminish, and at the fourth dorsal spine they are scarcely to be seen; but at the tenth they again increase in length, and form a triangular tendon. It some times happens that this muscle has no connexion with the eleventh and twelfth dorsal vertebræ. The long tendinous fibres of the two trapezii, at the junction of the cervical and dorsal regions, form an oval aponeurosis of considerable size, called the *cervical aponeurosis*, which is supposed to give greater strength to this part. All the spinal origin has its fibres blended with those of the opposite muscle, and supraspinal ligament. The insertion is by a mixture of tendinous and fleshy slips, except at the extremity of the spine of the scapula, where a little tendon is formed which glides over a small triangular surface to be inserted into the top of the tubercle. The plane which this muscle forms is curved on the side of the neck, and its fibres are there a little twisted. Instead of three sides this muscle has actually five: 1st, a superior; 2nd, an internal—these are its origins; 3rd, an external, which is its insertion, and two others which are unconnected, viz. 4th, an inferior external, and 5th, a superior external. Of these the first is so short that it attracts no notice; the other four are of unequal lengths—hence the name trapezius. But the third and fourth sides are so nearly in one continuous line that the whole muscle appears triangular.

The trapezius covers the complexus, the splenii, the levator anguli scapulæ, the serratus posticus superior, the rhomboidei, the supra-spinatus, a small portion of the infra-spinatus, the latissimus dorsi, the sacro-lumbalis and longissimus dorsi. It touches all these muscles, and glides on them by means of a fine cellular tissue, which contains little or no fat except over the supra-spinatus. The anterior superior edge forms the posterior boundary of the great lateral triangle of the neck, and at its upper extremity is often connected with the sterno-mastoid. The two trapezii have some resemblance to the monk's cowl hanging over the neck, hence the name *cucullares* often given to them.

By its superior fibres this muscle raises the clavicle and scapula; by its middle it draws the scapula towards the vertebral column, and by its inferior it pulls the tubercle of the spine of the scapula downwards. If all the fibres act together, it will cause the scapula to rotate on the thorax, so as to elevate the shoulder-joint, and in this it is powerfully assisted by the inferior portion of the serratus magnus, as in carrying heavy burthens on the shoulder. It serves to keep the head from falling forwards, and will, by its superior fibres, draw the head to the shoulder and turn the face to the other side. We use it in shrugging up the shoulders. It becomes a muscle of inspiration by raising and fixing the clavicle and scapula, so that the subclavius, the lesser pectoral, part of the serratus magnus, &c. may elevate the ribs. The spinal accessory nerve (the superior external respiratory of the trunk) terminates in this muscle, and, according to Sir Charles Bell, associates it with the other respiratory muscles.

The *ligamentum nuchæ*, from which the chief part of the cervical portion of the muscle arises, is a line of dense cellular tissue, extending from the external tuberosity of the os occipitis to the spine of the seventh cervical vertebra. It is interposed between the two trapezii. A thin septum extends from it to the spines of all the cervical vertebræ. In no part does it deserve the name of ligament in the human subject. In quadrupeds, however, especially where the neck is long or the head very heavy, as in the horse, stag, elephant, &c. it is a powerful elastic ligament, resembling in structure the ligamenta subflava of the spine, and is of great importance by supporting the head without much muscular effort. In man it is quite rudimental.

The trapezius presents much variety in different animals. In the carnivora and rodentia the clavicular portion joins with the *masto-humeral*, (a muscle not found in man,) and is separated from the scapular portion by the levator anguli scapulæ. In the horse the only part of the muscle developed is that which corresponds to the ascending fibres in man, and which are inserted into the tubercle at the extremity of the spinous processes. In the dolphin it is thin, covers all the scapula, and is inserted into that bone near its neck. In the mole a fleshy bundle coming from the loins replaces it. In birds it consists of two portions, one for the furca, the other for the scapula. In reptiles there is no trapezius.

Latissimus dorsi.—This muscle is also thin, triangular, and very extensive, covering the lumbar region, a part of the dorsal and of the side of the thorax, and contributing to form the posterior boundary of the axilla. It is exposed by raising the integuments, superficial fascia, and lower angle of the trapezius. Then we find it *arising* from the tops of the spinous processes of six, (sometimes of four or five, sometimes of seven or eight,) of the inferior dorsal vertebræ, of all the lumbar vertebræ and from the supraspinal ligament, from the spines and other eminences of the sacrum, from nearly the whole posterior half of the crest of the ilium, and from the three or four lowest false ribs. The fibres all converge, the uppermost running transversely, the lowest vertically. It is *inserted* into the posterior edge of the bicipital groove of the humerus.

The costal origin of this muscle is fleshy, all the rest is tendinous. The tendinous fibres on the vertebræ are blended with those of the opposite muscle, and on the sacrum and ilium with the glutæus maximus. They form a tendon of great extent, narrow on the sacrum, very broad on the lumbar region, and again becoming narrow as we ascend to the dorsal. It is to this tendinous expansion that the name of *lumbar fascia* is given; its fibres are for the most part in the direction of the fleshy fibres which succeed, but they are crossed irregularly by some others. This fascia covers and binds down the lumbar muscles, giving great strength to the loins; it is intimately connected with the tendon of the serratus posticus inferior, the internal oblique of the abdomen, and the posterior tendon of the transversalis, all of which are inseparably connected with its anterior surface. The costal origin is by fleshy slips which indigitate with similar slips of the obliquus externus abdominis; these are so disposed that the inferior almost conceals the one above it, and so on. The muscle on its way to the humerus glides over the inferior angle of the scapula, from which it receives a small fasciculus of fleshy fibres; then it bends under the teres major, forms a tendon about an inch broad and an inch long, which is connected at first by cellular tissue, and afterwards by a bursa mucosa to the front of the teres major; and is inserted into the inner or posterior edge of the bicipital groove. Some fibres of this tendon line the groove, a few pass up along its edge to the lesser tuberosity. The axillary vessels and nerves, the biceps and the coraco-brachialis, are in contact with its tendon.

The upper edge of the latissimus is nearly horizontal, slightly curved—its concavity upwards and free. The anterior edge is nearly vertical, and for the most part free also. The posterior or inner edge is connected throughout, and takes an extensive irregular sweep. On raising the muscle, we shall find that it was in contact with the serratus posticus inferior, the sacro-lumbalis and longissimus dorsi, the internal oblique and transversalis of the abdomen, the inferior rhomboid, the serratus magnus, the inferior angle of the scapula, the infra-spinatus and teres major, also with some of the ribs and intercostal muscles.

We sometimes meet a fasciculus of muscular fibres passing from the latissimus dorsi to the pectoralis major across the axillary vessels and nerves. In the Edinburgh Medical and Surgical Journal, vol. viii. Dr. Ramsay states that it is found in one subject out of every thirty, and may prove inconvenient to the axillary artery, vein, and nerves.

The latissimus dorsi depresses the arm, draws it backwards and inwards, rotates the humerus so as to turn the palm of the hand first inwards, then backwards. It serves to keep the lower angle of the scapula in its place. When the arm is raised and fixed, it draws the body up, as in climbing, or elevates the ribs, as in difficult respiration. In using crutches the arm is fixed by grasping the handle of the crutch, then the pectoralis major and latissimus pull up the body on the cross-bar towards their insertions; and when the body is so raised, it is impelled forwards by the action of this muscle, aided by the feet and by the body's own gravity.

In quadrupeds it is a muscle of progression, pulling the trunk forwards to the fore-leg, which was previously fixed. The *panniculus carnosus*, which is inserted close to it into the humerus, assists in this action. In birds it is small, and consists of two portions.

Second layer.—This layer consists of the *rhomboidei* and *levator anguli scapulæ*. They are seen on raising the trapezius.

The *rhomboidei* form a broad thin plane, separated only by a line of cellular tissue into the *minor* and *major*, extending from the spine to the scapula, and nearly concealed by the trapezius.

The *rhomboideus minor arises* from about half an inch of the ligamentum nuchæ and from the spine of the seventh cervical vertebra; its fibres run downwards and outwards to be *inserted* into the base of the scapula at and a little above the commencement of the spinous process of that bone. The *rhomboideus major*, three or four times as broad, *arises* from the four or five uppermost dorsal spines, runs downwards and outwards, and is *inserted* below the last into the base of the scapula from its spinous process to its inferior angle. These two muscles are of the same length, thickness, and appearance in every respect, differing only in breadth. Their fibres are parallel to each other, being tendinous at their origin, where they are blended with those of the trapezius, and are inserted between the serratus magnus and the supra- and infra-spinati. The insertion of the *major* is peculiar; a tendinous band runs along the base of the scapula from its spine to its inferior angle, and it is into this, not into the bone, that the muscular fibres are inserted, nearly at right angles. This band is attached only at its two extremities; it is not seen till we cut a few of the posterior fleshy fibres which do reach the bone. This arrangement is supposed to allow of greater freedom of anastomosis between the scapular vessels. The *minor* is overlapped at its insertion by the levator anguli scapulæ, in the rest of its extent by the trapezius. The major is covered by the trapezius principally; a very small part of its inferior angle is covered by the latissimus, and between these it is separated from the integuments only by the superficial fascia. The rhomboids get their name from their shape. Their opposite, but not their adjacent sides and angles are nearly equal. Their internal and external edges are attached; their superior and inferior are free. The inferior edge of the major is a little longer than any other. The deeper surface of these muscles touches the splenii, the serratus posticus superior, sacro-lumbalis and longissimus dorsi, some ribs and intercostal muscles.

These muscles draw the base of the scapula towards the spine, acting with most effect on the inferior angle, and thereby depressing the point of the shoulder. With the trapezius they draw the shoulders upwards and backwards.

In the simiæ the rhomboids extend to the occiput. In carnivora the *levator major scapulæ* seems to be their occipital portion. In the horse the *levator proprius scapulæ* is the anterior part of the rhomboid, arising from the ligamentum nuchæ.

The *levator anguli scapulæ* is a long strap-shaped muscle, situated on the side of the neck, and extending from the superior cervical vertebræ to the upper angle of the scapula. Its *origin* is by four (sometimes three) tendinous bundles from the posterior tubercles of the transverse processes of the four superior cervical vertebræ; that which arises from the atlas is the largest; they are intimately connected with the splenius colli behind, and with the scaleni before. The fleshy fibres proceeding from them unite, and passing downwards, outwards, and backwards, are *inserted* into the inner surface and posterior margin of the scapula, from its superior angle to near its spine. Here it overlaps a little of the lesser rhomboid, and is so united with the serratus magnus that Dumeril considers it a portion of this muscle. The dissection of it in some quadrupeds favours this opinion, but in man it appears rather in connexion with the rhomboid.

This muscle is covered by the sterno-mastoid at its upper part, then by the integuments, and afterwards by the trapezius. It rests on the splenius colli, cervicalis descendens, transversalis colli, serratus posticus superior, and lesser rhomboid.

This muscle pulls the superior angle of the scapula upwards and forwards, and by rotating that bone on the thorax becomes a depressor of the shoulder-joint. The rhomboids act with it in depressing the joint; but the inferior portion of the serratus magnus is its direct antagonist. When the trapezius acts with this muscle, the scapula is drawn directly upwards. If the scapula be fixed, this muscle will incline the neck to its own side.

This muscle undergoes many modifications in the different families of the *mammalia*. In simiæ it is inserted into the spine of the scapula, not into its angle. In carnivora and rodentia it separates the two portions of the trapezius, and is inserted near the acromial end of the spine of the scapula. In the cat it arises from the basilar process of the os occipitis and from only one of the cervical vertebræ, the atlas. In the horse it does not exist at all. In the dolphin it forms a thin tendon which spreads over the scapula. As to birds and reptiles, it is replaced in them by other muscles.

Third layer.—Two very thin muscles, the *serratus posticus superior* and *serratus posticus inferior*, constitute the layer.

The *serratus posticus superior* is quadrilateral. It *arises* by a thin tendon from the lowest part of the ligamentum nuchæ, from the last cervical and the first two or three dorsal spines. The fleshy fibres which succeed form a thin plane, pass downwards and outwards, and are *inserted* by four digitations into the superior border and external surface of the second, third, fourth, and fifth ribs, a little external to their angles.

This muscle is covered by the rhomboid, the trapezius, and, when the shoulder is drawn back, by the serratus magnus. Its origin is united to the two former. It covers the splenii, the longissimus dorsi, transversalis colli, sacro-lumbalis and cervicalis descendens; while on these it is tendinous; then it becomes fleshy and covers the ribs and intercostal muscles. Sometimes it has only three points of insertion. Occasionally we find a bundle of fibres passing from the upper part of this muscle along the levator anguli scapulæ to be inserted into the transverse process of the atlas.

This muscle elevates the ribs and expands the thorax as in inspiration. It binds down the muscles on which it lies, enabling them to act with more effect.

The *serratus posticus inferior* is very like the last muscle, but a little broader and thinner. It *arises* from the last two dorsal and first three lumbar spines by a thin tendinous expansion, which is intimately connected with the tendon of the latissimus dorsi, and often destroyed in removing the latter. The fleshy fibres which succeed pass upwards and outwards to be *inserted* by digitations into the four lowest false ribs. The uppermost digitation is the largest, and is attached to the rib near its angle; the others become smaller as we descend, and their insertions are more remote from the angles. The lowest is connected with the cartilage of the last rib. This muscle covers the longissimus dorsi and sacro-lumbalis, the ribs and intercostals. It also covers the posterior tendon of the transversalis abdominis, to which it is inseparably united.

This muscle draws down the ribs as in expiration, and binds down the deep lumbar muscles.

A thin semitransparent fibrous layer, called the *vertebral aponeurosis*, covers the spinal muscles in the interval between the two serrati. It is continuous with their adjacent edges, and assists them in binding down the long muscles of this region. The fibres of which it is composed pass for the most part transversely, from the spinous processes to the angles of the ribs.

These muscles are generally present in the inferior animals, when ribs exist, and have no peculiarity worthy of being noticed here.

The *splenii* form the *fourth* layer. They appear as one muscle, extending from the lower cervical and upper dorsal spines obliquely upwards, outwards, and forwards, to the head and to the transverse processes of the superior cervical vertebræ. Covered below by the rhomboid and serratus posticus superior, higher up by the trapezius and levator anguli scapulæ, and higher still by the sterno-mastoid, it is only about the middle of their course that they become distinct from each other, for they arise as one.

The *splenius colli* (or *splenius cervicis*) is the inferior portion, not so thick or broad as the superior, but of greater length. It *arises* from the spines of the third, fourth, fifth, and sixth dorsal vertebræ, and from the interspinal ligaments, by tendinous fibres which are long, and form an acute angle below. The flat band of fleshy substance which proceeds from this tendon passes upwards, outwards, and forwards, then divides into two or three fasciculi, which are *inserted* tendinous into the transverse processes of the two or three superior cervical vertebræ, blended with the attachments of the levator anguli scapulæ and the transversalis colli.

The *splenius capitis*, the superior portion, *arises* from the spines of the two superior dorsal vertebræ and of the seventh cervical, and from the ligamentum nuchæ as high as the fourth cervical. At the origin it is tendinous; it soon becomes fleshy, passes upwards, outwards, and forwards, to be *inserted* into the back part of the mastoid process of the temporal bone, and into the external part of the depression on the occipital, between the superior and inferior transverse ridges.

These two portions ought not to be considered distinct muscles. They are inseparable below; their structure, direction, and uses are alike; and they are inserted similarly—the one into transverse processes, the other into a part of the cranium perfectly analogous.

The splenii cover the longissimus dorsi, the complexus, the transversalis colli, and the trachelo-mastoideus. The splenii of opposite sides pass off from each other as they ascend, leaving a triangular space at the upper part of the neck, in which the complexi appear.

The action of these muscles is to incline the head to one side, and rotate it. If the sterno-mastoideus of the same side act with them, the head is inclined directly to the shoulder. If the splenii of opposite sides act together, the head and neck are kept erect, and in this they are assisted by the complexus and trapezius. They strap down the deeper muscles. Their name is said to be derived from some resemblance to the spleen! *(Turton's Glossary.)*

The *splenii* are generally better marked in other mammalia than in man. In the mole they are particularly strong. In carnivora there is no splenius colli. In the horse the splenius capitis is inserted into the mastoid process by a tendon common to it and to the trachelo-mastoideus. Birds have no splenius. Reptiles have analogous muscles; but fish have not.

Fifth layer.—On removing the splenii and all those previously described, we expose the *fifth* layer of muscles, consisting of the sacro-lumbalis, longissimus dorsi, spinalis and semi-spinalis dorsi, cervicalis descendens, transversalis colli, trachelo-mastoideus, and complexus. These, excepting the last, are long and slender, quite different from those hitherto described. They are also less distinct from each other. The first four of them fill up the vertebral groove from the sacrum to the neck, and might well be considered as one muscle—the *erector spinæ*.

The *sacro-lumbalis*, placed most externally, *arises* from the posterior surface of the sacrum, from the margin of the ilium where the latter overlaps the former, from the sacro-iliac ligaments, and from the extremities of the transverse processes of the lumbar vertebræ; passing upwards, and tapering in form, it is *inserted* by tendinous slips into the angles of all the ribs. It is reinforced in its ascent by accessory fibres *(musculi accessorii)*, which arise at the upper margins of the five or six lowest true ribs, internal to their angles, run upwards and outwards over one or two intercostal spaces under cover of the longer fibres, and are inserted with them into the angles of the ribs. These accessory fibres constitute almost the entire of the muscle at its upper part.

The *longissimus dorsi*, placed along its inner side, *arises* from the spinous and transverse processes of the lumbar vertebræ, and from the spines of the sacrum and its posterior surface down to its apex. It forms a thick, somewhat square, mass in the loins; on the dorsum it becomes flat and tapering, and ends in a point at the top of the thorax. It is *inserted* by two rows of tendinous and fleshy slips—one row into the transverse processes of all the dorsal vertebræ, the other row, externally, into the lower edge of the ribs near their articulations with those processes. The costal slips are seldom inserted into all the ribs, the first two or three and the last two or three being often without them.

The posterior surface of these two muscles consists below of a strong tendinous layer, from which a great part of their fleshy fibres arises; it is common to the two as far as the middle of the lumbar region; there it terminates on the sacro-lumbalis, but ascends much higher on the longissimus dorsi, separating into several distinct bands, between which vessels and nerves come out.

This tendon is not to be confounded with the fascia lumborum, which is much thinner and adheres to its posterior surface.

The *spinalis dorsi** lies close along the spinous ridge, *arising* from the two superior lumbar, and three inferior dorsal spines. It forms a thin muscle and is *inserted* into the nine superior dorsal spines. Below it is in contact with the longissimus; above it is separated from it by the next muscle.

The *semi-spinalis dorsi arises* from the transverse processes of the dorsal vertebræ from the eleventh to the sixth inclusive by so many distinct tendinous fasciculi which pass up, become fleshy, unite and are *inserted* into the spines of the four or five superior dorsal and two inferior cervical vertebræ. The name of this muscle is intended to denote its attachment to the transverse as well as to the spinous processes. It is at first concealed by the longissimus dorsi, then lies along the inner side of that muscle and the outer side of the spinalis dorsi, with which last it is often united in description.

These four muscles elevate the spine, and give it an inclination to their own side. The sacro-lumbalis will also depress the ribs slightly.

The *cervicalis descendens* looks like a continuation of the sacrolumbalis, between which and the longissimus dorsi it arises. Its *origin* is by tendinous slips from the angles of the second, third, fourth, fifth, and sixth ribs. These are at first blended with those of the sacro-lumbalis; then they unite and form a slender muscle, which runs upwards, outwards, and forwards, to be *inserted* into the transverse processes of the third, fourth, fifth and sixth cervical vertebræ, between the transversalis colli and the levator anguli scapulæ.

This muscle may elevate the ribs or exten the neck, turning it to one side. It is ofte considered as a portion of the sacro-lumbalis and sometimes called musculus accessoriu or cervicalis ascendens. The name cervical descendens, that by which it is best known, wa given to it by Diemerbroëck, who describe

* Under the denominations *transversaire epineu*, which may be latinized *transversus spinæ*, Bich and some other continental anatomists include t *spinalis dorsi, semi-spinalis dorsi, spinalis colli,* a *multifidus spinæ*.—Ed.

it as *descending* from the neck to act on the ribs and elevate them.

The *transversalis colli* appears like a continuation of the longissimus dorsi, and as such is often described. It *arises* along its internal side by tendinous and fleshy slips from the transverse processes of the second, third, fourth, fifth, and sixth dorsal vertebræ. These unite, form a flat fleshy belly, which passes upwards, outwards, and forwards, to be *inserted* by similar slips into the transverse processes of the cervical vertebræ from the sixth to the second inclusive, between the cervicalis descendens and the complexus. The origin and insertion of this muscle are connected only to transverse processes—hence the name.

This muscle elevates the neck and inclines it to one side.

The *trachelo-mastoideus* lies to the inner side of the transversalis colli, by which it is in great measure concealed. It *arises* by tendinous slips from the transverse processes of two or three superior dorsal, and of three or four cervical vertebræ. The slender muscle enlarges as it ascends, passes a little outwards, and is *inserted* into the posterior border of the mastoid process, underneath the splenius capitis. Its inner side rests on the complexus, then it covers the obliquus capitis inferior and superior, and the origin of the digastric, also the occipital artery. It is by some called the complexus minor, from the resemblance it bears to the complexus in its structure. Some anatomists consider it as the cranial portion of the longissimus dorsi and transversalis colli. The origin of its name is obvious.

When in action, this muscle extends the neck, drawing the head back and to its own side.

The *complexus* is thicker and broader than he muscles we have been now describing in he cervical region. It *arises* from the transverse and articulating processes of the four or ive superior dorsal vertebræ, and from the ransverse processes of the four inferior cervical, y tendinous slips: these are followed by leshy and tendinous bundles. The muscle hus formed passes upwards and inwards, to be *nserted* into the os occipitis between its supeor and inferior oblique ridges. The complexi re close to each other above, separated only y cellular tissue which is connected with the gamentum nuchæ; lower down, however, iere is some space between them. This muse is covered by the trapezius above, by the lenii in the middle, and by the tracheloastoideus and longissimus dorsi at its lowest art. It rests on the spinalis colli, the obliqui id recti capitis. The name is derived from e complicated intermixture of tendinous and shy fibres of which it is composed. A surficial portion of it is described by Albinus the *biventer cervicis*, but it does not usually mit of subdivision.

This muscle draws the head back on the inal column.

In the muscles of this layer there are no y striking differences to be observed in the other mammalia, nor in birds. Reptiles and fishes differ too widely to allow of a comparison.

Sixth layer.—On raising the complexus and trachelo-mastoideus we observe a beautiful series of muscles for moving the head, viz. the *inferior oblique*, the *superior oblique*, the *rectus capitis posticus major* and *minor*. These, with the spinalis colli, form a *sixth* layer.

The *spinalis*, or rather *semi-spinalis* colli, *arises* by four or five fasciculi from the transverse processes of as many superior dorsal vertebræ; these unite, pass upwards and inwards, to be *inserted* into the second, third, fourth, and fifth cervical spines, forming a thicker muscle than the spinalis or semi-spinalis dorsi.

This muscle commences between the longissimus and semi-spinalis dorsi, then it lies between this last and the complexus. It is almost concealed by the complexus. It extends the cervical vertebræ and inclines them to its own side.

The *obliquus capitis inferior arises* from the spine of the second vertebra, passes outwards and a little upwards and forwards, to be *inserted* into the transverse process of the first. Its origin is connected with that of the rectus posticus major, and the insertion of the spinalis colli. Its insertion is blended with the origin of the obliquus superior. It is fusiform in shape, the largest of the four muscles to be met with here, and is often called *obliquus major*. It covers the vertebral artery and the lamina of the second vertebra, and is itself covered by the complexus and trachelo-mastoideus, and by the posterior branch of the first cervical nerve.

It rotates the first vertebra on the second, thus turning the face to its own side.

The *obliquus capitis superior* (or *minor*) has a pointed *origin* from the transverse process of the atlas; runs upwards, inwards, and backwards, becoming broader, and is *inserted* into the os occipitis between its transverse ridges, just above the insertion of the rectus posticus major. This muscle is covered by the splenius capitis, trachelo-mastoideus and complexus. It covers the vertebral artery and the interval between the atlas and occiput.

Its action is to extend the head, giving it some inclination to its own side.

The *rectus capitis posticus major* is triangular; its apex *arises* from the spine of the dentata; it passes upwards and a little outwards, to be inserted by its base into the inferior transverse ridge of the os occipitis. This muscle and its fellow arise close together; passing up they separate. The insertion is overlapped by that of the superior oblique. The complexus covers the greater part of it.

This muscle draws back the head, turning the face a little to its own side.

The two obliqui, with this last muscle, enclose a triangular space, in which we see the posterior branch of the sub-occipital nerve enveloped in adipose tissue, the vertebral artery, the posterior half ring of the atlas, and the thin ligament which connects this last with the edge of the foramen magnum. Here we find the nerve dividing into three branches for these three muscles.

On removing some cellular tissue from between the recti majores, we observe the

Rectus posticus minor, shaped like the last, but much smaller. It *arises* close to its fellow from a little tubercle on the back of the atlas, passes upwards, outwards, and backwards, to be *inserted* into the os occipitis between the inferior oblique ridge and the foramen magnum. It is partly concealed by the rectus major. This muscle can draw the head backwards.

In quadrupeds these four muscles are proportionally larger than in man. The inferior oblique and the rectus major are considerably larger. Birds have three recti, and only one oblique—the inferior. Reptiles and fishes may be said to want them, as the analogy is very remote.

On removing the spinalis colli and all the muscles of the fifth layer, we observe numerous fasciculi of muscular fibres, which are named *inter-spinalis*, *inter-transversalis*, and *multifidus spinæ*. These might be considered a seventh layer; but they are very analogous to the small muscles just described, and nearly on the same plane.

The *inter-spinales* are short bundles of fleshy fibres placed between the spinous processes of contiguous vertebræ. They are in pairs in the neck, where the spine consists of two laminæ. Here also they are well marked. In the dorsal region they are scarcely visible, and in the loins they are not easily distinguished from an interspinal ligament. They are analogous to the recti postici. They extend the spine.

On the lips of the spinous processes of the neck some fibres may be shown, to which the name supra-spinal muscles has been given. They extend farther than from one vertebra to the next.

The *inter-transversales* are similar fibres, scarcely to be demonstrated except in the neck, where they are in pairs, corresponding to the divided transverse processes.

The *multifidus spinæ* consists of separate bundles of fibres, extending from each transverse process obliquely upwards and inwards to the spinous process of the vertebra next above, or sometimes to the second above. The first bundle runs from the side or transverse process of the sacrum to the spine of the last lumbar vertebra; the last from the transverse process of the third cervical to the spine of the second. They are smaller as we ascend, and are not easily separated from the spinales and semi-spinales. They support the spine, and rotate one vertebra on the other slightly.

In the article SPINE, the practical utility of a knowledge of the muscles of this extensive region will be demonstrated.

For the BIBLIOGRAPHY of this article see that of ANATOMY (INTRODUCTION).

(Charles Benson.)

BILE. Syn. *Gall.* (Gr. χολη; Lat. *bilis;* Fr. *bile;* Ger. *die Galle;* Ital. *fiele.*)—This important secretion has been laboriously examined by several modern chemists of eminence, among whom we may especially enumerate Thenard,* Berzelius,† Tiedemann and Gmelin,‡ and Frommherz and Gugert.§ Their results, however, are so much at variance, that it is impossible to draw any general conclusions from them respecting the real nature and chemical components of the bile; these discrepancies seem partly to arise from the extreme facility with which chemical agents react upon this secretion, so that many of the supposed *educts* or component parts which have been enumerated, are probably *products* of the different operations to which it has been submitted, or at all events modifications of its true proximate elements: it has been therefore well observed by Berzelius, that our present chemical knowledge of the nature of bile can only be considered as a foundation for the more extended and satisfactory researches of future experimentalists. We shall here endeavour to select some of the least disputable and most important facts respecting the chemical properties of the bile, remarking at the outset to those who may be inclined to repeat the experiments which we shall cite, that the indications of re-agents upon different specimens of bile are apt to vary, and that their action is often much modified by temperature, quantity, and the mode in which they are used.

There always appears to be mixed with bile a variable proportion of *mucus*, probably derived from the gall-bladder and its ducts, and not, therefore, a true component of the secretion: this gives the bile its viscidity, and often seems in some way to modify its other characters: in general, however, *(ox-gall,)* it is a green liquid, varying much in tint, of a peculiar odour, a bitter and nauseous taste, and a specific gravity fluctuating between 1.020 and 1.030. It does not coagulate when heated, and although it may possibly contain albumen, or something very like it, it is not immediately coagulated by alcohol or by dilute acids. The relative proportion of solid matter obtained by evaporation is between eight and ten *per cent.* By means of acetic acid, the mucus which is mixed with the bile may to a great extent be separated. In the *mammalia*, generally, the bile exhibits nearly the same characters; and in birds and fishes its components seem to be the same, but rather more dilute in the former and more concentrated in the latter: it is always alcaline, from the presence of soda, apparently in the same state of combination as it exists in the serum of the blood. When bile is evaporated very carefully to about half its bulk, and alcohol added (in the proportion of about four parts to one of the evaporated bile,) a coagulated matter is thrown down, which has some of the prop[erties]

* Thenard, Mémoires d'Arcueil, i.

† Lehrbuch der Thierchemie. Dresden, 183[.] and Medico-Chirurgical Transactions, iii.

‡ Über die Verdauung (Essay on Digestion).

§ Schweigger's Journal, v. 1.

ties of albumen; yet neither solution of corrosive sublimate, nor of ferrocyanate of potassa, which are such delicate tests of that proximate animal principle in other cases, enables us to detect it in the original bile. When alcohol is added to bile which has been evaporated nearly to dryness, it acquires, when filtered off, a brownish green colour and bitter taste; when evaporated, it leaves a residue which is almost totally soluble in water; and in this aqueous solution, dilute sulphuric acid slowly throws down a grey substance, which appears to be a compound of the acid and the bitter principle of the bile; when it has been washed with water (in which it is not soluble), it dissolves in alcohol, and if the sulphuric acid be then separated from it by carbonate of baryta and filtration, the filtered solution leaves on evaporation a green, transparent, bitter residue, which appears to be the characteristic principle of the bile, and which Berzelius calls *Gallenstoff*. As thus obtained, it is not quite free from foreign matters, and ether digested upon it takes up a little fatty matter; indeed when bile, concentrated by evaporation, is agitated with ether, and the latter, after having separated upon the surface, is poured off and evaporated, it always leaves traces of a fatty substance, probably identical with *cholesterine*. The purified bitter residue, to which we have just adverted, is apparently the *picromel* of Thenard; it has a bitter, pungent, and sweetish taste, is inflammable, deliquescent, soluble in water and alcohol, but insoluble in ether; its solution is precipitated by many acids, (not by acetic or phosphoric,) and the precipitate is nearly insoluble in water, of a greenish colour, resinous appearance, and fusible at 212°. This precipitate (consisting of picromel combined with the acid used to throw it down) dissolves in alcohol, and is again thrown down by water: it dissolves in solution of acetate of potash, the alcali of which combines with the acid of the precipitate, whilst the acetic acid unites to the picromel to form a soluble acetate. Picromel dissolves in weak alcaline solutions apparently without decomposition.

It will be seen from many of the above characters, that picromel (by which we mean Berzelius's *Gallenstoff*) has probably been mistaken for albumen, and that it is not improbable that the only true albuminous part of the bile may be in that equivocal state which is often called *mucus*, and which is especially distinguished by being precipitable by acetic acid. Berzelius has suggested an analogy between picromel and the peculiar saccharine matter which is contained in liquorice-root; and in many respects their chemical properties are identical.

In the preceding statement, drawn principally from Berzelius, we have endeavoured to give the simplest view of the analysis of the bile; namely, the separation of its *muco-albumen* by acetic acid or alcohol, and of its *picromel*, by precipitation with acids and subsequent decomposition of the precipitate by carbonated baryte or alcali; its saline contents appear closely to resemble those of the serum of the blood; like which it has an alcaline reaction, due to soda. We have also selected such experiments, as, with us, have invariably succeeded: the following results, therefore, of the analysis of the bile, as given by Berzelius, will now be intelligible.

Water	90.44
Picromel, (Gallenstoff,) including fat	8.00
Mucus of the gall-bladder	0.30
Extractive, common salt, and lactate of soda	0.74
Soda	0.41
Phosphate of soda and lime and traces of a substance insoluble in alcohol	0.11
	100.

The details of the other analyses of the bile as given by the authorities to which we have referred above, would be unintelligible if abridged, and are too voluminous, and too exclusively chemical, to be inserted here; and moreover, we have generally failed in arriving at satisfactory conclusions in our endeavours at a repetition of the various analytical operations which are described; we must therefore rest satisfied with giving, in a condensed form, a general statement of their results. According to Thenard, *human bile* contains, water 90.90; yellow bitter resin 3.73; yellow matter generally diffused through the bile (mucus and colouring matter?) 0.18 to 0.90; albumen 3.82; soda, by which the resin is dissolved, 0.51; phosphate, sulphate, and muriate of soda, phosphate of lime, and oxide of iron, 0.41. Tiedemann and Gmelin give the following as the components of human bile: 1. fat; 2. brown resin; 3. sweet principle of bile; 4. salivary matter; 5. mucus; 6. gall-brown (colouring matter?); 7. oleic acid, salts, and minute quantities of other substances. Frommherz and Gugert* have arrived at yet more complicated results: namely, 1. fat; 2. resin; 3. sweet principle; 4. osmazome; 5. salivary matter (Speichelstoff); 6. caseum; 7. mucus; 8. margaric and other fatty acids, with phosphate, muriate, and sulphate of soda and potash; and carbonate, phosphate, and sulphate of lime. The above, and other chemists, have published analyses of bile, taken after death in various diseases, but they present nothing very important. Tiedemann and Gmelin's elaborate analysis of *ox-gall* deserves the perusal of all chemists concerned in such inquiries: it contains, according to L. Gmelin,† a substance not to be found in any other bile, and which he has called *Taurin* or *Gallenaspa-ragin*: it may be obtained as follows:—add muriatic acid to ox-gall and filter; after a few days a fatty matter appears, which is separated by filtration; the filtered liquid is evaporated to a small bulk, when it separates into two parts, a resinous mass and a sour fluid: the latter, upon further evaporation, yields more resinous matter, and at length crystals of com-

* M. Schweigger's Journal, vol. l. p. 8.

† L. Gmelin, Handbuch der Theoretischen Chemie, ii. 1012. Frankfurt, 1829.

mon salt and taurin, which are to be separated, and the latter purified a second by crystallisation. Taurin, when purified, is in prismatic crystals, neither acid nor alkaline, not altered by exposure to air, inodorous, of a peculiar taste: soluble in about fifteen parts of cold water, and nearly insoluble in absolute alcohol: it is fusible, and not decomposed by nitric acid.

In concluding this subject, we must again express our conviction that many of the supposed proximate components of bile are *products* of the various operations and re-agents to which it has been submitted, and that the analysis of Berzelius, which is the simplest, is probably the most correct: from the uncertain operation of various precipitants upon bile, and from the facility with which the results vary, apparently in consequence of very trifling causes, there seems to be a peculiar tendency in its component parts to undergo hitherto unexplained modifications.

Biliary calculi, or *gall-stones.*—These concretions have been especially examined by Gren, Thenard, Fourcroy, and as to the fatty matter which they contain, by Chevreul.* Human gall-stones are, for the most part, composed of a crystalline aggregate of a species of adipocere, or as it has been termed by Chevreul, *cholesterine*, (from χολη, *bile*, and στερεος, *solid*,) with more or less colouring matter, muco-albumen, and inspissated bile; they are accordingly of various colours and textures, but generally brittle and friable. Those which are chiefly cholesterine, or as it should more properly be termed *cholestearine*, are white and crystalline, and lighter than water; the others are more tough, coloured, and dense; their specific gravities, therefore, vary from 0.803 to 1.06. Their chemical examination may be conducted as follows: they may be powdered, and digested in water to separate the inspissated bile: then boiled in alcohol, and the solution filtered whilst hot; as it cools it deposits the cholesterine, and often retains common fat and its acids in solution. The portion which resists the action of alcohol may be digested in a weak solution of caustic potash, which takes up colouring matter and muco-albumen: the solution, supersaturated by acetic acid, deposits these, and the colouring matter may afterwards be removed by alcohol. Any common albumen may be detected by ferrocyanate of potash added to the acetic solution.

Cholesterine separates in white pearly scales from its hot alcoholic or etherial solution during cooling; it fuses at about 280°, and when heated to about 400°, it sublimes: in the open air it burns like wax. Its ultimate components are 85 carbon, 12 hydrogen, 3 oxygen. It is the most carbonaceous of all the varieties of fat.

The gall-stones of the ox frequently consist chiefly of the yellow colouring matter of the bile, which is occasionally used by painters on account of its brightness and durability: it is insoluble in water and alcohol, but readily soluble in weak solution of potash, from which it is thrown down in green flocks by muriatic acid: nitric acid cautiously dropped into a solution of this colouring matter gives it various shades of green, blue, and red.

* Annales de Chimie, xcv. 5.

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(W. T. Brande.)

BLADDER, (in anatomy.) (Gr. κυστις. Lat. *vesica*, *vesicula*. Fr. *vessie*, *vesicule*. Germ. *Blase*. Ital. *vescica*).—This term is employed to denote a membranous sac, more or less complicated in its structure, with one or more orifices, and destined as a reservoir for particular fluids. We have, for instance, in most animals provided with a liver, a gall-bladder or reservoir for the bile; in fishes we have a swimming-bladder, *vesica natatoria;* and in the females of several insects, mollusca and crustaceans, a bladder, recently described by Audouin, Milne Edwards, Des Hayes, and others, the function of which is to receive, during copulation, the prolific fluid from the male, and which has, therefore, been called *vesicale copulatrice*. In fine, in a great number of the animals provided with a urinary apparatus we have a urinary bladder, *vesica urinaria*. For a particular description of the first three varieties of bladder we refer to the articles Liver, Pisces, and Insecta;—that of the urinary bladder forms the subject of the succeeding article.

(R. B. Todd.)

BLADDER OF URINE (normal anatomy).—(Κυστις ουροδοχος, *vesica urinaria*. Germ. *Harnblase*. Commonly known as *the* Bladder.) The urinary, like the biliary apparatus, consists of four principal organs, each accomplishing a different purpose, yet all contributing to the same end, namely, the separation from the circulating medium of a considerable portion of aqueous and saline matter: these are, first, the *kidney* or *kidneys*, which are the principal, indeed the sole agents in this function; secondly, the *ureters*, the excretory ducts, whose office it is to convey the fluid secreted, drop by drop, as fast as it is formed, which is by a slow and gradual process, to, thirdly, the *urinary bladder*, which serves merely as a temporary receptacle for it; and, fourthly, the *urethra*, or terminating excretory tube, whereby this fluid is wholly discharged from the system.

A urinary bladder has not been ascertained to exist in any of the invertebrate division of animals, and in the vertebrate there is a great diversity with respect to it: thus in the class Pisces, this organ is absent in all the osseous family, in most of whom, however, the two ureters unite below, and form a slight heart-shaped dilatation which opens externally behind the anus in common with the sexual organs: this vesicle, though somewhat analogous to, cannot be considered as a perfect reservoir. In most of the cartilaginous fishes it is absent also, as in the ray and shark, in whom the ureters open as in birds into a cloaca, or reservoir common to the renal, sexual, and intestinal discharges; in some, however, of this family it is present, as in the cyclopterus or lump-fish, the lophius piscatorius, &c.; in the latter it is very capacious, and its coats are so thin as to be transparent; it receives the ureters anteriorly, and opens, as is usual in fish, behind the anus, in common with the genital ducts.

In Reptilia, the bladder is present in some, as the Batrachia and Chelonia; it is absent in all the Ophidia, and in many of the Sauria, as the crocodile, the gecko, and the lizard; while again it exists in many of the same division, as the iguana, chameleon, draco, &c. In the Batrachia, as the frog and the toad, it is situated in front of the rectum or cloaca, into which it opens; the ureters open into the latter posteriorly, from whence the urine is directed into the bladder by the muscular contraction of the cloaca and of the sphincters of the anus. In the frog its cavity is large, parietes thin, and its fundus divided into two cornua. In the Chelonia, as the tortoise, it is very large, and the ureters open into the urethra anterior to its cervix, the urine must therefore return or reascend to enter the bladder. In the Ophidia or the Serpent tribe, each ureter dilates inferiorly into a small vesicle, which then opens into the cloaca, and there is no other approximation to a bladder; in such of the Sauria as this organ exists, it opens into the cloaca.

In Aves the bladder is always absent; in the whole of this extensive class, the ureters open into the cloaca, and the urine, which is so earthy as to appear almost solid, is there mingled with the fæces, in common with which it is discharged at short and repeated intervals. In the Ostrich and Cassowary the cloaca is very dilatable, and its muscular structure is so organized as to be enabled to retain within it, and to discharge occasionally a considerable quantity of urine; hence in these animals a vesica urinaria has been by some erroneously supposed to exist.

In all mammalia this organ exists, and in every member of this class the ureters enter it obliquely at a little distance behind the cervix, with the exception of the ornithoryncus and monotrematous animals generally; in these the ureters open into the urethra a little beyond or anterior to the cervix of the bladder, so that the urine must return or ascend, in order to enter its cavity; this curious arrangement is similar to that adopted in the chelonia, and would appear to indicate, as Carus ingeniously suggests, that in these strangely formed animals, in the same manner as in reptiles and in birds, the allantois (the remains of the urachus of which form the bladder in mammalia) arises from the expansion of the rectum or the cloaca, whilst in other quadrupeds it is solely connected to the genital passages. In all mammalia this organ presents a tolerably uniform appearance both as to structure and shape, but great diversity as to capacity or size; the latter appears to be in an inverse ratio to its muscularity: hence in Carnivora, the bladder being more muscular, appears smaller in proportion to the size of the animal than in some of the Herbivora, where its coats are thinner, and therefore more dilatable; in others, however, of the latter order, in whom it is very muscular, its capacity is inferior to that of some even of the carnivora: in the Rodentia it is muscular and small, particularly if contrasted with the genital apparatus. In quadrupeds the bladder is usually more covered by the peritoneum, and hence it appears more loose and free in the abdomen than in the human subject; its figure is usually rounded, pyriform, or oval; and it may be remarked (and the remark will even apply to the human child and embryo) that the younger the animal the more elongated is the bladder, a fact which is indicative of its derivation from, or *original continuity* with the urachus and allantois.

The urinary bladder in man is deeply seated in the anterior inferior part of the pelvis: it is composed of different tissues, membranous and muscular, both calculated to yield and to expand to a slightly distending force, so as to form a recipient reservoir, while the latter is fitted by its contractile power to obliterate the cavity of the organ, and forcibly to eject its contents. This musculo-membranous viscus demands the particular attention of the surgical anatomist, not merely as to its structure, but as regards its situation and connections, as it is the seat of many very severe and often fatal morbid affections, several of which admit of a perfect cure, and most of considerable relief, from operation and from various kinds of local treatment, the safe performance and judicious application of which greatly depend on a correct knowledge of the structure and relations of the organ. We propose first to consider the form and structure of the bladder in the normal state, and afterwards to describe its situation and connections.

Shape.—The figure of the bladder must vary according to its state of contraction or distention, in reference to which it is usual to consider it under three conditions, viz. the empty or contracted, the full or ordinarily distended, and the over-distended. Its figure in these different states also varies according to the sex and age of the individual, the bladder of the infant differing materially from that of the adult, and that of the adult female from that of the male; the bladder of the embryo also differs from that of the fully developed fœtus. The younger the animal, the more does its form resemble that of inferior animals, and it is an organ very fully developed in the young of all animals who possess it. This organ, in the adult male, when empty or contracted, is a flattened triangle, the transverse and vertical axes being considerably greater than the antero-posterior one; in this condition the bladder is buried deep in the pelvis, behind and partly below the symphysis pubis; the base of the triangle is in front of but not very closely applied to the rectum, unless the cavity of the latter be fully distended. When the bladder is expanded in the adult male to that moderate degree which in perfect health usually excites a slight feeling or desire to void the urine, and when the quantity accumulated may amount to half a pint or upwards, its figure is then somewhat oval, its vertical axis being considerably greater than either the transverse or the antero-posterior, the two latter being then nearly equal. The larger end of this ovoid sac rests inferiorly and posteriorly on the rectum, and is of an irregular form; the smaller end, which is more regularly spheroidal, is directed upwards towards the abdomen, and somewhat forwards, and occasionally also a little towards the left side. When the bladder is over-distended from any cause, it becomes considerably increased in every diameter; it first expands in its lower and middle portions, until the pelvic parietes resist; it then enlarges superiorly to an indefinite degree, and at the same time the whole organ rotates a little forwards by its superior, and a little backwards by its inferior fundus. Its figure in this over-distended condition is not merely enlarged, but it also presents a totally different, or rather a reversed shape: the larger extremity of the oval is now superior, occupying the hypogastric region, which it renders prominent and tense in a degree proportioned to its distension. These observations as to the form of the bladder will not apply in every instance, as occasionally this viscus presents irregularities both in size and shape, as well as in the density and delicacy of its tunics. The bladder in the female child does not differ from that of the male of the same age, but in the adult of each sex it presents peculiarities. In the contracted state it is nearly similar in each, only somewhat flatter in the female. When distended, in the latter it presents a more triangular form, the sides somewhat rounded, than it does in the male, where the ovoid form prevails; in the female its lower fundus admits of greater lateral extension in conformity with the shape of the pelvis, and its transverse axis is longer in proportion than in the male; hence it assumes the triangular more than the oval figure. This character is more remarkable in the female who has borne children than in the virgin; in the former the bladder, when distended, appears to exhibit the effects of the pressure of the uterus posteriorly, and of the pubes anteriorly, being flattened in each of these aspects: in some instanees it resembles a small barrel placed tranversely.

In the fœtus and infant of a year old the bladder in figure more resembles that of a quadruped; when distended, it is pyriform, like a bottle or a flask reversed, the larger end, or the superior fundus being in the abdomen, and the smaller extremity tapering into the urethra. This is the only portion in the pelvis; at this age its vertical axis greatly exceeds its other diameters, and even when empty the greater portion of it is in the abdomen. As the child increases in years and size, its pelvis expands, the bladder gradually descends into this region, and in the same proportion its lower fundus enlarges, so that at about six or seven years of age it presents a more oval form, both extremities being nearly equal, and very little of it rising above the pubis, unless when distended. From this period it continues to acquire gradually the adult figure; that is, its inferior fundus and body enlarge, while the superior remains stationary; hence it becomes shorter in its proportions, and broader below, so as to assume the triangular shape when empty, and the ovoid when distended. About two months before birth the bladder is very much elongated, its upper extremity being somewhat pointed, and approaching the umbilicus in the direction of the urachus. When distended, it presents somewhat the appearance of a cylinder contracted at each extremity. Soon after birth the upper fundus becomes rounder, and then it acquires the pyriform figure, which in the course of a few years undergoes the gradual alterations that have been already noticed.

The capacity of the bladder in the adult cannot be accurately ascertained, as it varies from a number of circumstances, such as age and sex, health and disease: thus irritation general or local, ischuria renalis, cholera, &c., will cause it to contract, while retention of urine, paralysis, fever, &c., will allow it to enlarge. Custom or habit will also affect it, likewise the position of the body, pregnancy, the nature or peculiar quality of diet, the temperament of the individual, the temperature of the atmosphere, the state of society, &c. In the same individual it will at one time contract so as to retain only a few drops, and at another it will dilate so as to contain one, two, and even three pints. Generally it is more capacious in women, particularly in those who have borne children, than in men.

In children the bladder, although very distensible under certain circumstances, is usually less capacious in proportion than in the adult or old, probably because it is more muscular and irritable; and hence, too, the more frequent desire to contract and empty its contents.

When the bladder is moderately distended, anatomists and pathologists have been in the custom of dividing it into four regions for the purpose of more accurate description; viz., the superior part or the upper fundus, the middle part or body, the inferior part or the lower fundus, and the cervix or neck. This arrangement is not very correct, for it can only apply to this organ when distended; the term superior fundus also is obviously objectionable, and was probably derived from examining this viscus in other animals, or in the human fœtus where the lower fundus does not exist; neither can any exact distinction, or even an approximation to such, be made between these several compartments. A more accurate knowledge of this organ may be obtained by examining both internally and externally its several aspects, which are six in number, and which may be regarded as distinct regions; viz., an anterior and posterior, two lateral, and a superior and inferior. We shall examine each of these externally, and defer any remarks on their internal aspect until we come to speak of the lining membrane or the mucous coat of the bladder.

The *anterior region*, in consequence of the obliquity of the pelvis, looks also downwards. When the bladder is contracted, this region is behind and in contact (cellular tissue only intervening) with the lower half or three fourths of the symphysis pubis, and with the pubic and triangular or interosseous ligaments; when distended, it rises above the bone, and is connected by an abundance of cellular and adipose tissue to the lower portion of the recti and transversi muscles; and as no peritoneum is there interposed, this part can be punctured with safety during life. At the lower border of this region is the neck of the bladder, the upper surface of which is firmly attached to the lower edge of the symphysis pubis by two horizontally placed fibrous cords, which are named the anterior ligaments of the bladder, and which will be more particularly noticed presently. Between and beneath these, some veins also run upon this surface of the bladder. The whole of this region is deprived of any peritoneal or serous covering.

The *posterior region* has an aspect upwards also; it is smooth and covered throughout with peritoneum. When the bladder is contracted, this small region in the male pelvis is in contact with the fore-part of the rectum, or with such of the floating abdominal viscera as may chance to intervene; in the female with the fore-part of the uterus. When this region is distended, it presents a broad smooth convex surface, which presses more against the rectum and supports the convolutions of the small intestines.

The *lateral regions*, when the bladder is contracted, are little more than margins or edges, and present nothing worthy of notice; but when distended, each becomes a broad surface, somewhat triangular, the base below and the apex above, the posterior portion, nearly the half, is covered by peritoneum, the anterior portion is connected by cellular tissue to the parietes of the pelvis: the obliterated umbilical artery ascends along its superior posterior portion, and the vas deferens, which crosses to the inside of the latter, runs along this region in an oblique direction downwards and backwards, and marks the anterior limit of the peritoneum. From this region the broad lateral fold of this membrane extends to the iliac fossa, and at its inferior border is that reflection of the vesical fascia which is named the true lateral ligament of the bladder.

The *superior region*, by some called the superior fundus, is, when the bladder is empty, little more than a point prolonged into the urachus; but when distended, it presents its large and convex surface upwards and forwards; to it is attached the superior ligament of the bladder, which consists of three fibrous cords, the urachus and the obliterated umbilical arteries; behind these this region is covered by peritoneum, but anterior to them it is not. The former portion is in contact with the convolutions of the small intestines, the latter with the recti muscles.

The *inferior region*, or the inferior fundus, or the base of some authors, always exists as a distinct surface, whether this organ be contracted or distended, but of course larger in the latter condition. It is rather more extensize in a transverse direction than from before backwards, and is larger and more distinct in the male than in the female: its lateral portions in each sex are in contact with the levatores ani muscles, and correspond to the spaces between the anus and the tuberosities of the ischium. In the female its middle portion is in contact with the vagina, in the male with the rectum in the middle line, and with the vasa deferentia and vesiculæ seminales on either side; to the latter it is closely connected. The cellular and adipose tissue on and around this region in the adult is very abundant, and contains numerous veins. This region is covered posteriorly by peritoneum, which extends to a transverse line connecting the centre of each vesicula seminalis. This line corresponds to the convexity of the cul-de-sac formed by the reflection of this membrane from the bladder to the rectum. In front of this line this region is covered in the middle only by a fascia and by some cellular tissue as far as the base of the prostate gland, which extends for some distance along its anterior portion, and on either side are the vasa deferentia and the anterior terminations of the vesiculæ seminales. When the bladder is distended in the adult, this surface is enlarged, not only in superficial extent, but it also swells backwards and downwards towards the rectum, and even presses against and into that intestine, so as in some rare cases to admit of being felt by the finger introduced per anum. To this portion the name of 'bas fond' is commonly applied. In the adult this bas fond, that is, the posterior part of this region, is the lowest portion of the bladder, and hence cannot be evacuated except by the contraction of the organ or by surrounding pressure. In man, in advanced life, it is often found dilated into a sort of pouch, which is behind and quite below the level of the anterior part of this region, as well as of the neck of the bladder, forming in some instances of debility a sort of permanent reservoir, and one in which calculi are not unfrequently contained. In the fœtus this pouch or fundus does not at all exist, the cervix or the urethral opening being then the most depending part, which circumstance offers another reason for the power of retention of urine being less at that age than at a later period of life. Some writers limit the inferior region to so much of this aspect of the bladder as is uncovered by peritoneum, and therefore consider the posterior part of it as appertaining to the posterior region. Anatomically we consider this incorrect, as the vesiculæ seminales are acknowledged by all to be situated on the inferior region, and the cul-de-sac of the peritoneum certainly descends between these bodies to within nearly one-half or three-fourths of an inch from the prostate gland. In a practical point of view it is most essential to keep this in mind, because in the operation of recto-vesical paracentesis this membrane is endangered, and would certainly be perforated if the trochar were passed through the posterior portion of this region. The surface of the bladder which can be opened from the rectum in that operation is comparatively small; it is of a triangular form, nearly equilateral, situated on the anterior part of this region. The base is behind marked by the convex border of the peritoneal cul-de-sac: the apex is at the notch in the base of the prostate gland, and the sides are the vasa deferentia and vesiculæ seminales. While all these parts are in situ, this space is but small; when, however, the bladder has been removed from the subject, distended, and dissected, this space appears much more ample, because the peritoneum recedes from it in proportion as the attachments of the former have been loosened.

The bladder presents to our notice three diameters, viz. the transverse, antero-posterior, and the vertical; the latter is also called its axis. In the contracted state the antero-posterior can scarcely be considered as existing; but when distended, this and the transverse diameters are nearly equal. In all states, at least in the male, the vertical diameter or axis is the longest; this line leads in the adult from the centre of the upper region to that of the lower region or fundus: in the fœtus and infant it leads from the urachus to the orifice of the urethra; if this line be contrasted with the axis of the trunk or abdomen, and with that of the pelvis, it will be found to correspond very nearly with the direction of the latter, and to pass very obliquely with respect to the former. The axis of the trunk may be regarded as nearly a vertical line, descending through the thorax and abdomen to the pubis, whereas the axis of the pelvis, or rather of its superior orifice, will pass obliquely downwards and backwards, and if produced at either end, it will pierce the recti muscles between the umbilicus and pubis anteriorly, and the lower end of the sacrum posteriorly. The vertical axis of the bladder in the adult is on a lower plane, but nearly parallel to that line; in the fœtus it is more parallel to that of the trunk, the bladder at that age being placed more in the abdomen, and in a more vertical direction than in the adult.

The bladder is composed of several membranous laminæ, called coats or tunics: these are essentially three in number, a serous, a muscular, and a mucous. They are connected together by cellular tissue, the laminæ of which being two in number are also considered coats; so that the whole number of tunics is stated by most writers as five. First, the serous or peritoneal is but a partial coat; it covers those portions only which come in contact with some of the abdominal or pelvic viscera, namely, all the posterior region, and the posterior portions of the lateral, and of the superior and inferior regions; consequently it is deficient on all the anterior region, and on the anterior part of the superior, and of the lateral and inferior regions. The course of the vasa deferentia marks the extent or the limits of this membrane on the bladder; all that portion which is behind and between these tubes is covered by it, except the small triangular area already noticed on the inferior region; all that which is anterior to these vessels is uncovered by this membrane. The peritoneum arrives at this viscus from the fore-part of the rectum in the male, and from that of the uterus in the female, and is continued from its lateral regions to the iliac fossæ, and from its superior fundus to the inside of the recti muscles. This membrane is not very closely attached to the subjacent coat; it can be easily separated from it; it is much stronger and more elastic on this organ than on any of the chylopoietic viscera. When the bladder is distended, there is more in proportion covered by peritoneum than when it is contracted. The female bladder has more of the peritoneum on its upper fundus, and less on its lower fundus than the male bladder, and in the fœtus and infant it is still more extensively covered by this membrane, which then extends over the whole of the upper region and over a small portion of the anterior. As the peritoneum passes from the sides of the bladder to the iliac fossæ, it forms folds, improperly called the lateral ligaments, and in passing from the back of the bladder to the rectum or uterus, a similar fold on each side, called the posterior ligaments of the bladder. Between these the cul-de-sac of the peritoneum descends; this in the male subject is the lowest portion of the peritoneal cavity, it extends to within about three inches and a half of the anus: in ascites it has been known to be somewhat lower, and has even been tapped in this situation from the rectum.

2dly. The external or first cellular coat connects the serous to the muscular tissue; it also covers those regions of the bladder where the serous membrane is deficient. In the lateral regions it is more distinct and thick, and is particularly abundant anteriorly between it and the pubes, where it is also very lax, to allow this organ when distended to move freely as it rises out of the pelvis into the abdomen. It contains some but not much adipose matter; towards the inferior and lateral parts it contains many bloodvessels, chiefly venous, and a great number of nerves, which can be distinctly traced from thence in all directions over the bladder. Towards the vesiculæ it is dense and white, and supports a number of veins; this coat is strong, resisting, and elastic; it binds together, supports, and assists the muscular fibres.

The third coat of the bladder is the muscular: this is composed of fasciculi running in different directions, and which, though they appear pale and feeble when contrasted with the voluntary muscles, are yet much stronger and redder than those in the corresponding coat in most of the other hollow viscera, being intermediate in these respects to those of the stomach and œsophagus; this tunic, however, presents great diversity as to colour and density in different individuals. In the contracted state of the bladder, it of course appears more dense than in the distended; in the latter, but particularly in the over-distended state, it appears thin and imperfect in some places, in consequence of the fasciculi being separated from each other. In the young, *cæteris paribus*, it is stronger than in the old, and in the female than in the male; but long-continued irritation at any age and in either sex has the effect of thickening it, as also any disease which causes obstruction to the flow of urine. If the bladder be removed from the body, slightly distended and subjected to maceration for a few hours, this tunic will admit of more distinct examination; its fibres will then be seen to take such different directions as to admit of a tolerably easy, though not a perfectly natural separation into distinct laminæ, the fibres in the first or superficial of which have a longitudinal course; beneath this is a second stratum, whose fibres are transverse or circular; and in some situations even a third lamina can be distinctly seen, the fibres of which are by some described under the name of oblique, but the term reticular would appear more correct: in general these three laminæ can be made distinct, particularly on the anterior part of the bladder. The first or longitudinal lamina consists of the longest, strongest, and most numerous fasciculi; many of these are connected superiorly to the urachus, thence they descend principally on the fore and back part of the bladder, a few only along the sides; inferiorly they terminate about the neck. These fibres are very parallel, and much stronger on the anterior and posterior aspects than upon the sides, where they run more obliquely or irregularly, and decussate with one another. The inferior attachment of these fibres in the male subject may be ascertained by careful dissection to be as follows:—those on the fore part of the bladder are connected chiefly to the anterior ligaments, or to the reflections of the fascia from the pubis on this organ; these appear as shining and distinct as tendons, and have been by some considered as such to these muscular bands. Above this insertion these longitudinal fibres appear very numerous, and those on the right and left of the median line distinctly decussate or interlace. Several here also take a transverse or an arched or semicircular course; some of these are very distinct and are inserted laterally; they must serve to strengthen and to bind down the longitudinal fasciculi. The latter in this situation can be divided into layers, the superficial of which only are inserted, as has been described, into the anterior ligaments of the bladder, and through these into the pubis. The deeper set are inserted, some into the dense cellular tissue about the upper surface of the prostate, and some pass deeper, and intermingle with that circular musculo-cellular tissue which surrounds the cervix, and which constitutes the true sphincter. Some of those longitudinal fibres, particularly more laterally, pass so deep in this situation as to be very distinctly seen, when the bladder is opened, through the mucous lining of the orifice of the urethra. This disposition of the longitudinal fibres we consider as important, as it must enable them during their contraction to draw out or expand the sphincter, so as to allow of the escape of the urine. Laterally these longitudinal fibres are attached, a few of them to the margin of the prostate, while others expand over the lateral lobes of this gland, and are inserted into the fascia which covers it. Posteriorly these fibres are very distinct, particularly near the inferior surface of the bladder between the two ureters; to these last-named tubes several of these fibres are connected: some ascend upon them in arches concave upwards; these we have traced several inches along the ureters; while others descend in the same course with them, and are inserted into the trigone of the bladder. The longitudinal fibres collect into a strong flat band between and beneath the two vesiculæ, over which however no fibres pass as they do over the prostate, which circumstance clearly separates these vesicles from, while the contrary disposition rather connects the prostate with, the urinary excretion. This band of fibres can be followed near to the base of the prostate; some of its fibres are then inserted into the submucous fibrous tissue in this situation, others into the base of the gland itself; and very generally one long delicate but distinct band enters the notch in the base of the gland, passes beneath the uvula and middle lobe of the prostate, into which it is sometimes inserted, but it can frequently be traced nearly an inch further forward to be inserted by a delicate tendon beneath the seminal caruncle or the verumontanum, which is partially covered over by a fold of mucous membrane or by a sort of prepuce. The effect of this band of the longitudinal fibres must be to depress the uvula, and thus to open the orifice of the urethra, and also to depress and to draw the seminal caruncle (a sort of organized glans) downwards and backwards within the prepuce or sinus pocularis, which covers it, and thus protects it from the irritation of the urine. In the female the longitudinal fibres are inserted anteriorly and laterally into the cellular, glandular, and vascular tissue which surrounds the neck of the bladder, and posteriorly into a more dense tissue which connects the urethra to the vagina; some fibres also pass in deep, as in the male, to be attached to the sphincter. This muscular lamina is described by the older authors as a distinct muscle, the '*detrusor urinæ*,' arising from and around the urachus by numerous fibres, which thence descend and expand over the whole surface, and again concentrate towards the neck of the bladder to be inserted by one or two tendons into the ossa pubis. This account, however, is by no means perfectly correct; for on attentively examining this muscular lamina, we frequently find strong transverse fasciculi crossing superficially to the longitudinal fibres, most frequently on the anterior region, but also near the neck. Occasionally some of the longitudinal fibres alter their direction gradually or abruptly, as may be particularly noticed about the ureters and also on the lateral regions. Great diversity exists as to the arrangement of this tunic in the lower animals: thus in the dog this plane consists of strong and regularly parallel fibres, whereas in the ox they assume a reticular and irregular course: in man they resemble the arrangement of the carnivorous more than that of the graminivorous animals. This tunic must have the effect of compressing the bladder towards the ossa pubis, and of course urging the contents of the cavity in that direction, while at the same time some of its fibres will expand the orifice of the urethra by drawing out the sphincter above and on either side, and below by depressing the uvula and the verumontanum. This stratum of muscular fibres can be raised with a little careful dissection; a few fibres must be divided, which now and then change their direction, and join some of the deeper orders: this separation is difficult and can be but imperfectly made on the lateral regions, but on the anterior and posterior it can be fully accomplished. The second order of muscular fibres is circular or transverse; they are paler, weaker, and more scattered than the former, particularly towards the superior part of the bladder, where they are often indistinct. As they descend they increase in thickness, particularly near the cervix, where they are so close and distinct as to have induced many to consider them as a sphincter to the bladder,—a term, however, to which they do not appear to have been entitled, for there is no distinction between the fibres in this situation and those which have a parallel course at a greater distance; and inasmuch as the latter are obviously designed to contract the organ and to expel its contents, it is most probable that the former must contribute to the same effect, and forcibly expel the last drops which it contains: indeed it is impossible to draw such a line of distinction in this lamina as could denote the limit between the expelling and the retaining or sphincter fibres. In addition to this plane of circular fibres, several others may also be observed taking a parallel direction; thus we occasionally find transverse bands superficial to the longitudinal plane, both on the anterior and posterior regions in different situations. We very generally also find them near the superior fundus, and constantly on the anterior and lateral parts of the neck, where they cover the decussation of the longitudinal fibres. In the interval between the ureters, these transverse fibres are very distinct, particularly above, where they usually form a very distinct cord, arched a little upwards: this semilunar band or projection may be better seen when the bladder is opened; it corresponds to the base of the trigone, extends from one ureter to the other, and is immediately in front of the pouch or bas fond of the bladder, which is so well marked in the adult and old. Throughout the rest of the trigone the circular fibres are by no means so distinct or strong as they are behind it, or as they are towards the anterior and lateral parts of the cervix. This circular plane of fibres may next be raised; it is almost impossible to do this completely, because many of them deviate from that course, and join into the next or third lamina, taking a totally different course; the separation, however, can be accomplished sufficiently to demonstrate the peculiar arrangement of the third plane of fibres, not all over the bladder, but only in particular situations, namely, in the greater part of the anterior and posterior regions, but only very imperfectly on the superior fundus, and on the sides, and not at all on the trigone. Wherever this third layer is exposed, the fasciculi appear very large and thick, and present a very remarkable appearance and course, not unlike the inner surface of the cavities of the heart. Large fleshy bundles, bearing some resemblance to the carneæ columnæ, separate, unite again, and again subdivide, the fibres taking various directions, and inclosing interstices of the mucous surface of various size and form: several of the fibres also join those of the circular plane. It is owing to this reticularly arranged stratum of muscular fibres that the bladder, when opened, presents its peculiar irregular surface, which in some cases, particularly if the bladder have been hardened in alcohol, resembles a honeycomb surface. If the bladder which has been opened be everted, then carefully closed and distended, this reticular coat will become very distinct when the mucous membrane has been removed. Its action during life must obviously be to contract the capacity of the bladder in every direction. When the internal surface of the bladder, even in the healthy state, is inspected, the different orders of muscular fibres become very apparent; and when this coat has become thickened from any of those causes which are well known to produce thickening, some of the fasciculi often project into the bladder: such a condition of the organ is named a columnar state of the bladder. In cases of irritable bladder, when calculous symptoms have been present, and the bladder has been sounded in consequence, these fleshy projections meeting the extremity of the sound, have in some instances deceived the surgeon into the idea of the existence of a calculus, and this is still more likely to occur should there be any gritty matter adhering to their surface. Some of those recorded cases of the operation for lithotomy, in which no stone could be detected, although the symptoms of the disease previously existed, may admit of explanation by a knowledge of this fact. In the bladder of some persons the muscular fibres do not perfectly cover the mucous surface, particularly if the organ be very capacious. In such cases the mucous membrane may be pushed through some of the cells or meshes of the muscular fibres, and thus a hernia of the mucous coat be produced; that is, a small pouch or purse of this membrane will protrude between the muscular fasciculi, and will be covered only by peritoneum or by cellular tissue. This pouch may continue to increase in size, because it possesses no power of emptying itself, and the muscular fibres around its orifice can only contract the latter without affecting the sac itself; hence a process of this sort may enlarge indefinitely, and has been known in some cases to have formed a part of the contents of an inguinal hernia. Pouches of this nature, for there may be several in the same individual, sometimes contain calculi, the latter having probably been the cause of the former, inasmuch as the muscular coat having been excited by the irritation of the stone to increased action, has forcibly pressed the latter into one of the cells of the mucous membrane, which has then become enlarged and protruded, so as to contain the calculus impacted in it. The consequence of this occurrence to the individual, however, is often a fortunate remission of suffering, because the stone being now fixed in a cell, ceases to excite pain or irritation: it is by occurrences of this nature that the boasted and sometimes fortunate efficacy of certain lithontriptic medicines as cures for stone is to be explained.

The exact arrangement of the muscular fibres at the neck of the bladder has not been very accurately explained; some describe them as arranged circularly so as to constitute a true sphincter: this opinion is maintained by John Bell, System of Anatomy, vol. iv. p. 159; also by Palfin, Anat. tom. i. p. 163; by Meckel, Anat. vol. iii. p. 564; by Bayle and others. Sir Charles Bell also describes a sphincter vesicæ to exist, but places it in a different situation from that usually assigned. His description of this muscle is as follows:—"to exhibit it, cut off all the appendages to the bladder except the prostate gland, make an incision into the fundus and invert it, dissect off the inner membrane from around the orifice of the urethra; a set of fibres will be discovered on the lower half of the orifice running in a semicircular form round the urethra; these make a band of about half an inch in breadth, particularly strong on the lower part of the opening, and having mounted a little above the orifice on each side, they disperse a portion of their fibres in the substance of the bladder; a smaller and weaker set will be seen to complete their course surrounding the orifice on the upper part, to these sphincter fibres a bridle is joined which comes from the union of the muscles of the ureters; this is the most posterior part of all the muscles which embrace the urethra, it resembles the sphincters of the other hollow viscera; for example, that of the pyloric orifice of the stomach."* The great advantage of the sphincter as thus described must be, as Sir C. Bell says, to prevent the fluids from the seminal vessels and from the ducts of the prostate gland, falling back into the bladder, as also to protect the orifices of these ducts from exposure to the urine when the bladder is closed, and that without this arrangement it would be inconceivable how the contents of the vesiculæ seminales could be discharged forwards, or how the urine could be retained while the seminal discharge was being made. We must remark, that after frequent examinations of this region, we cannot satisfy ourselves of the existence of this particular arrangement, although we are convinced that the orifice is furnished with a sphincter such as we shall presently describe. Moreover, we believe that the prostatic secretion is more or less expressed at each evacuation of the urine, inasmuch as the longitudinal, the principal detrusor fibres of the bladder, are fixed into, expand upon, and must compress this gland, especially at the commencement of the process, although they obviously can have no effect on the vesiculæ seminales, vasa deferentia, or their contents.

The existence of a true muscular sphincter is denied by Sabatier, Anat. tom. ii. p. 403; Marjolin, tom. ii. p. 473; also by Bichat, Anat. desc. tom. v. p. 147; by Boyer, Anat. tom. iv. p. 490; by Cloquet, Anat. tom. ii. p. 1050; by Portal, Anat. tom. v. p. 401; the latter, however, describes the urethral orifice as surrounded by oblique muscular fasciculi. Winslow also, Anat. tom. ii. p. 210, denies a true sphincter, but ascribes the office of such to the muscular fasciculi which pass from the pubis to the bladder. Wilson (Lectures on the Urinary and Genital Organs, p. 57,) denies the existence of any regular sphincter, but thinks, from the distribution of some fibres at the beginning of the urethra, and which pass round it semicircularly from the forepart and meet the descending fibres behind, that the contraction of these, assisted by those of the urethra nearer the penis (compressores urethræ), may be considered as sufficient to prevent the urine passing from the bladder into the urethra. Several of the foregoing writers who deny a muscular sphincter to the bladder, consider, nevertheless, that its orifice is closed by a peculiar tissue which resists the ordinary tendency of the muscular coat to expel its contents, but which is capable of yielding to the increased force which is exerted in the ordinary evacuation. Thus Bichat describes, as placed between the mucous lining and the external cellular tissue, a dense white fibrous substance, continuous with the muscular fibres which are inserted into it, a small process of this prolonged posteriorly to the uvula, and another anteriorly to the verumontanum. This substance is not muscular, and presents a passive organic resistance. Cloquet, Boyer, and Marjolin concur in the same account; it is difficult, however, to reconcile with such a condition of parts the phenomena which not unfrequently occur in disease, such as paralysis and incontinence of urine in cases of injury of the spine, or of the nervous system; or again, retention of urine from irritation in this situation caused either by local inflammation, or through sympathy with some adjacent diseased organ, or by some peculiar acrimony in the urine. A muscular structure is more reconcilable with these, and with many other pathological facts, than an elastic, or fibrous, or resisting tissue, such as this part is stated to be furnished with. The result of our examination convinces us that the organization of this part is very peculiar, and that the neck of the bladder is closed by a power more than that of a mere elastic tissue. Elasticity no doubt resides in this structure, and we admit to a considerable extent, as it does in almost every ani-

* Treatise on Diseases of the Urethra, &c. p. 14.

mal tissue, except perhaps mucous membranes; elasticity exists at the pylorus and at the anus, although true muscular and sphincter fibres are evident at both these outlets. When this region is carefully examined in the male subject, we shall find that immediately behind the pubis, on the anterior and lateral reflections of the pelvic fascia, to these ligaments numerous muscular fibres of the bladder are attached; these are chiefly longitudinal, but there are also several transverse arched or semilunar, some upon, and others underneath the longitudinal fibres, and with which many of them are continuous. None of these arched fibres pass around or behind the prostate so as to encircle this region. The longitudinal, the transverse and decussating or interlacing fibres in this situation, are in greater abundance, and may be raised in successive laminæ. Veins and nerves are very manifest in and between these; several of the longitudinal fibres of the deeper laminæ pass in so deeply as to approach the mucous surface. When the several strata of longitudinal fibres have been raised from the front and lateral parts of this region, the circular fibres of the bladder become distinct, but do not appear so proportionably increased as were the longitudinal; but on detaching more completely the longitudinal strata down to the circumference of the very opening of the urethra, a distinctly fibrous, that is, muscular tissue, is evident, bounding this opening laterally and superiorly, but not below. This muscular fasciculus is not intimately connected to the general circular coat; it appears redder, and of a closer texture, and will be found to be attached to the fibrous or tendinous substance forming the anterior part of the trigone on each side of the uvula, behind which it does not pass. The longitudinal fibres are inserted partly into this semicircular muscle, much in the same manner as the levatores ani are inserted into the circumference of the anus. This structure we consider to be partly elastic, but essentially muscular; it bounds the urethral opening laterally and above, but not below; the slight projection of the uvula in the latter situation, and the elasticity and gentle state of contraction natural to all the sphincter muscles, will preserve this opening in a constantly closed state during the quiescent and normal condition of the parts. This arrangement is on a level with the uvula, and, of course, behind the orifices of the prostate ducts, although the base of that gland extends further back than this sphincter. We have repeatedly examined beneath the uvula for muscular fibres, but have found none in a transverse direction; there is, therefore, no portion of a sphincter in that spot, and hence one advantage of the slight elevation caused by the uvula and by that portion of the prostate gland denominated its middle lobe, which corresponds to it: indeed sphincter fibres in this spot would be not only useless, but injurious, as they could scarcely exist without interfering with the ejaculatory ducts. We conceive, then, that the urine is retained in the bladder partly by the relaxed or passive state in which its muscular coats usually remain until they are excited by the sense of distension, partly also by the urine, when only in a moderate quantity, gravitating, not towards the neck, but distending the inferior fundus, which lies on a level lower than that of the former, and principally by the dense muscular, elastic, vascular, and nervous tissue which surrounds three-fourths of the orifice of the bladder. The gentle contraction of the latter raises the uvula into the calibre of the opening, while the remaining sides are pressed into contact with it, and thus the bladder is closed. When distension excites the usual feeling, the muscular coat contracts, the sphincter relaxes, phenomena exactly corresponding to those which take place under similar circumstances in the rectum and anus; and as the levatores ani expand the anal opening by drawing the sphincter fibres outwards at the time the expulsive powers of the rectum are discharging its contents, so the longitudinal fibres of the bladder draw out from the axis of the urethral opening the relaxed sphincter which encompasses three-fourths of it, while the middle band of the posterior longitudinal will plainly depress the uvula and expand the orifice in that aspect, and will even retract and depress the verumontanum, thereby freeing the passage into the urethra, and retracting that sentient caruncle from the irritating influence of the urinary stream.

The next coat of the bladder, the fourth of some anatomists, or the second common of others, is the deep cellular, or more properly the submucous cellular coat, by some also denominated the nervous tunic. This coat invests the whole organ and connects the muscular and mucous tissues intimately yet loosely; it contains no adipose matter, but is very filamentous, extensible, and elastic: in it are found those vessels and nerves which are to supply the internal surface of the bladder, and which, except in some situations, are not very numerous when compared with those in the other hollow viscera. This coat, though essentially cellular, presents very many fibrous threads through it, on which much of its strength appears to depend, particularly in those places where the muscular coat is deficient. When the bladder is fully distended, if we dissect off the muscular fibres carefully without injuring this tissue, the mucous membrane still remains supported; but as soon as a portion of this coat is detached, the mucous membrane projects in an unsupported sacculated manner. This coat corresponds with that elastic tissue in the parietes of the small intestines in some animals, out of which the substance, commonly termed catgut, is formed.

The third proper coat is the mucous or lining membrane, to expose which the bladder must be opened by a perpendicular incision along its anterior region. This tunic is but a portion of the genito-urinary mucous membrane, and is continuous with that lining the ureters above, and the urethra below. The vesical portion of this membrane is very thin, has a soft and smooth feel caused by the mucous fluid which lubricates it; its colour is very pale in the natural condition although in catarrh or in chronic inflammation it presents a general vascular appearance; bu in health the mucous surfaces of the intestinal tube and of this organ form a strong contrast, more particularly if the vessels of both have been injected with coloured size; the former will then assume the colour of the injection, the latter will continue pale, although numerous vessels become apparent in the submucous tissue. The mucous lining of the bladder in the healthy state does not present any distinct follicles or cryptæ except near the cervix, which become very distinct in chronic disease. A cuticular or epidermoid covering cannot be detected in health, although in certain states of disease a substance very similar to cuticle is occasionally discharged in shreds and flakes. When the bladder is empty and contracted, the mucous membrane is thrown into numerous rugæ, existing chiefly in a transverse direction, which are most distinct if a very recently contracted bladder be examined. When the organ is distended, these rugæ disappear, so that their existence may be considered as evincing a want of elasticity in this tissue. This membrane presents some peculiarities throughout the extent of a small region named the 'trigone' or the 'velum' of the bladder: this term is applied to a small triangular space, nearly equilateral, situated about the middle of the inferior region, and leading to the neck of the bladder. The base of this space is a lunated line leading from the orifice of one ureter to the other; the sides are marked by lines which converge forwards from these openings to a slight projection at the neck of the bladder named the 'uvula,' which is immediately behind or rather in the orifice of the urethra. Throughout the area of this space the mucous membrane is very smooth and free from rugæ or folds, as it adheres closely to the fibrous or compact cellular substance beneath: it is also more vascular, being generally of a delicate rose colour, or variegated with fine vessels, and when minutely examined with a magnifying lens numerous fine villi can be discerned. On the whole this surface appears to be delicately and peculiarly organized, and no doubt possesses higher sensibility than the remainder of the internal surface of the organ. The posterior part of the trigone is thinner than the anterior; the line which marks its base is a thickened band of the circular or transverse muscular fibres, behind which the inferior fundus of the bladder is frequently dilated into a pouch which presses against the rectum, and where a calculus sometimes rests, so as to elude the search of the sound unless the finger be introduced into the rectum: in old persons this pouch sometimes remains constantly full of urine, the muscular coat of the bladder not being able to contract it. The lines which form the sides of the trigone, and which extend from the orifices of each ureter to the uvula, are composed of a slight projection of the mucous membrane, beneath which is some cellular tissue, and in some cases a few pale muscular fibres are distinctly seen. These lateral lines are not in general very distinct, at least in the healthy bladder; their distinctness is owing to little more than being the borders of this space. In some cases, particularly when the prostate has been enlarged or the urethra obstructed, they are found very distinct, the muscular fibres they contain being thickened even in a greater degree than the other portions of the muscular coat of the bladder. These lateral fasciculi appear to be little more than some of the longitudinal muscular fibres of the bladder converging towards its cervix. Sir C. Bell, however, has attached a particular importance to these muscles, which he denominates the "muscles of the ureters:" his description of their attachments and use is as follows, in his own words:—"The use of these muscles is to assist in the contraction of the bladder, and at the same time to close and support the mouths of the ureters." "They guard the orifices of the ureters by preserving the obliquity of the passage, and by pulling down the extremities of the ureters according to the degree of the contraction of the bladder generally."*

It appears very questionable how far this statement as to the structure of these lines is generally correct, and it is still farther doubtful whether the use assigned is correctly ascribed or not; for it may be remarked that these lines are often very faintly traced, that the muscular structure within them is sometimes very indistinct, that in females it is scarcely observable, in very young children also of either sex it is not well developed; whereas if such an important office as that of guarding the ureters depended on these muscular fibres, it is most probable, and indeed is even certain that their presence would be constant and their development more uniform. Again, the fact of the dead bladder when fully distended with fluid, or even with air when the urethra is tied, and the contents not escaping through the ureters, is a strong proof that the oblique or valvular direction of the latter is the true cause of the non-regurgitation, and that it does not depend on the contraction of any particular muscular fibres. Again too, in animals this structure, as described by Sir C. Bell, is not at all obvious although the ureters have the same oblique course as in man; it would rather appear that these muscular bands, which are occasionally very distinct along the sides of the trigone, are only portions of the longitudinal fibres, and that their action will be to shorten the trigone, to draw its base forward, and thus to assist in emptying the bladder. They may doubtless assist in fixing the orifice of the ureters and moving these in proportion as the surrounding parts are affected, but the opinion that the preservation of the valvular or oblique course is depending upon them appears to be invalidated by the foregoing remarks, as well as by the following experiment. The healthy bladder of an adult male, recently dead, was opened to a small extent on its fore-part, and the sides of the trigone were cut by a sharp-pointed bistoury passed beneath each of them; the urethra was then tied, and the bladder carefully closed: its cavity was next fully distended with water, and the fluid was

* Medico-Chir. Trans. vol. iii. p. 178.

retained for a considerable time although it was subjected to pressure, and was afterwards evacuated through the urethra when the ligature on the latter was removed. No alteration whatever from the ordinary appearances was observed either during the distension or the subsequent emptying of its cavity, nor did any regurgitation take place into the ureters in either state. The same experiment with air instead of water was repeated and with the same effect. It may be further observed that the ductus communis choledochus enters the duodenum in a similar oblique way, that no regurgitation from the intestine ever occurs into it, and yet there is no peculiar muscular fasciculus attached to its orifice which could execute the office ascribed to these lateral boundaries of the trigone. To these muscles Sir C. Bell also attributes the projection into the bladder of the third lobe of the prostate gland, usually called *the middle* or *Home's lobe*, when this part is in a state of enlargement. There are, however, such plain and simple reasons for this tumour becoming prominent in this direction rather than in any other, that it is unnecessary to search for an explanation in the action of these muscles, the undoubted development of which in such cases may with a much greater degree of probability be considered as one of the effects and not as the cause of this projection.

The uvula or apex of the trigone varies very much in its appearance in different persons. In the normal state it is very small, and is most distinctly seen by making only a small opening in the upper region of the bladder when in situ, and looking down towards the cervix; it then appears as a small projection in the middle line of the orifice of the urethra, which opening it thus assists to close or to fill. It is much effaced by opening the bladder from the urethra after its removal from the subject, the mucous membrane being then easily extended. This projection is only a slight fullness or prominence of the mucous membrane with an increase in the submucous tissue, in which small follicles or cryptæ may be discerned. This part appears rather vascular, and probably possesses some peculiar organization; the situation also which it holds, as well as its structure, appear to indicate it to be the seat of a proper sensibility, which, when affected, excites the irritability of the whole organ. Many facts which manifest themselves in the treatment of urinary diseases seem to corroborate this idea: thus, when a calculus is pressed against this part of the mucous membrane, the pain is insupportable, whereas when it falls or is directed into the inferior fundus, the pain is comparatively trifling; also when a bougie or catheter is being passed into the bladder, a peculiarly acute sensation is experienced as the instrument comes in contact with this particular prominence. The uvula in the child is the most depending part of the bladder, at least in the erect posture; this is not the case in the adult; hence probably we have in part the reason why calculus is more painful in the former than in the latter.

The trigone in the female bladder comprises a smaller area, but is broader in proportion than in the male; it is not so distinct or firm in the former as in the latter, where it is supported not only by a dense substratum, but also by the vasa deferentia, vesiculæ seminales, and prostate gland. This portion of the bladder is so firm and incompressible that it is probable the cavity corresponding to it can never be wholly obliterated, so that in the most contracted bladder a few drops of fluid are still retained. The uvula, like other similar portions of the mucous membrane, is subject to infiltration and increase of size in acute inflammatory affections, as also to chronic and permanent enlargement; and as it lies nearly over, but a little anterior to the middle lobe of the prostate gland, it is therefore difficult, and in most cases impossible to distinguish affections of the latter from those of the former. The uvula is smaller in the female than in the male; hence the opening from the bladder into the urethra is larger in the former than in the latter.

Organization of the bladder.—a. *Arteries.*—In the normal state the bladder is not very vascular; we have already mentioned that its inner surface is pale and free from any red vessels. The arteries, however, of the bladder are very conspicuous when they have been injected; they are long and tortuous, and are distributed chiefly along the sides, inferior region, and cervix. They are derived from various sources. The internal iliac or hypogastric on each side, just before its ligamentous termination, sends off one or two vesical branches, which ramify on the superior and lateral regions; the middle hæmorrhoidal and internal pubic also very generally send some considerable branches to its inferior region and cervix; the obturator and epigastric vessels also very frequently send small arteries to it anteriorly. When the bladder is distended, all these vessels are seen very distinctly, and in the muscular coat much more than in the submucous tissue, contrary to what may be observed in the other hollow viscera; this, however, is accounted for by recollecting that the mucous coat of the bladder does not in its normal and healthy condition possess, nor does it indeed require any high degree of organization, as it is simply a reservoir, and has no important function to execute further than to secrete a fine mucous fluid which lubricates its surface and defends it from the irritation of the urine. This secretion mingles with the urine the properties of which it alters in a remarkable manner whenever it is increased in quantity, as occasionally occurs in chronic disease of this organ. The muscular coat of the bladder is the essential agent in expelling its contents, and is therefore more fully supplied with vessels than any other of its tunics.

b. *Veins.*—The veins of the bladder are large and numerous inferiorly, and in old persons in particular. There are but few on the superior and lateral regions except towards the inferior part of the latter. In the child the veins are very inconsiderable: this difference depends on this circumstance, that the veins which are seen at the inferior region of the bladder, and which return the blood from its tunics, do not belong exclusively to this organ, but are principally derived from the dorsal veins of the penis; they also receive several branches from the vesiculæ and the prostate, also from the rectum and intervening adipose substance. In the adult and old these latter veins are very numerous, indeed they may be said to form a perfect 'venous plexus' on each side, extending from the termination of the ureter to the prostate gland. All these veins are considerably less developed in children, inasmuch as the organs, at least those of generation, from which they are principally derived, are comparatively small. The vesical veins ultimately discharge their blood into the internal iliac or hypogastric veins.

e. *Lymphatics.*—The lymphatic vessels are tolerably distinct, more particularly inferiorly and about the cervix. They intermingle with the lymphatics of the rectum and of the neighbouring organs, and ultimately lead to the internal iliac or hypogastric glands. Independent of dissection, the existence of absorbents in the bladder is proved by its functions, or by the changes which the urine undergoes when long retained in this cavity,—a portion of its water is absorbed, and the residue becomes pungent, high-coloured, and acrid.

d. *Nerves.*—The nerves of the bladder are derived from the hypogastric plexus, which is constituted of two orders of nerves, viz. some from the sacral plexus of the spinal system, and others from the sympathetic or ganglionic system. This two-fold supply of nerves accords with the functions of this organ, and entitles it to be placed, as far as relates to the properties of its muscular coat, among the mixed muscles, being in part voluntary and in part involuntary: the former endowment will, of course, depend on its share of spinal nerves, the latter on the sympathetic. It may also be observed that the branches of the latter are principally distributed about the cervix and inferior region, while those of the former are seen distinctly on the sides and superior regions; but in all these situations these nerves are more or less intermingled.

The cervix of the bladder is of a compressed conical form, longer below and on the sides than above. It is surrounded in the male by the prostate gland; only a small portion of this is upon its upper surface: in the adult the neck is placed nearly horizontally below the pubis and behind the triangular ligament. In the female the cervix vesicæ is closely surrounded by a whitish compact follicular texture, not possessing any perfect capsule, and therefore without the accurate form of or any resemblance to the prostate gland in the male. The cervix in the child is more distinctly conical, and is placed in a more oblique or vertical direction than in the adult. The term cervix is not very definitive, as there is no exact limit, at least in the human subject, to mark this region as in quadrupeds; according to most writers on human anatomy, it is synonymous with the prostatic portion of the urethra, and the full description of it is given by such in connexion with the anatomy of the urethra. We consider the neck of the bladder to be that contracted portion of the viscus which is embraced by the base only of the prostate gland, and which contains internally and below the slight elevation named the uvula of the bladder, and laterally and above the peculiar structure which fulfils the office of a sphincter.

Having particularly noticed the situation of the bladder, and the slight change of position it admits of in consequence of its change in form, we shall next consider its attachments, or the media by which it is retained in its position, for it may be considered as nearly a fixed viscus. The bladder is held in its position principally by three connexions; first, by the peritoneum; secondly, by the reflections of the pelvic fascia; and, thirdly, by the continuity of its cervix with the urethra, the commencement of the latter being fixed by ligamentous connexions to the arch and rami of the pubes. First, the bladder is connected by certain folds of the peritoneum to the parietes of the pelvis and abdomen; these folds are named the "false ligaments" of the bladder, and are five in number, two lateral, two posterior, and one superior. Each of the lateral ligaments or folds extends from the lateral region of the bladder to the iliac fossa, and contains in its duplicature the vasa deferentia in the male, and the round ligament of the uterus in the female.

The posterior folds or ligaments are also two in number; they lead from the fore-part of the rectum to the back part of the bladder. Each of these folds is of a semilunar form, (the concavity looking forwards and upwards,) and contains the ureter posteriorly, and the obliterated hypogastric artery anteriorly. When the bladder is distended, these posterior folds are very short; but when it is contracted, they are distinct and long. Between them the pelvic cul-de-sac of the peritoneum descends, which in the empty state of the bladder and rectum appears deep, narrow, and distinct, but in the distended condition of these organs, particularly of the former, it is of much less extent and depth, as the bladder in becoming distended rises upwards and draws with it the cul-de-sac of the peritoneum: hence in the distended state of this organ the triangular portion of its inferior region which is uncovered by peritoneum is increased in extent, and is larger than when the organ is contracted. Between the two posterior ligaments one or two semilunar folds of the peritoneum may be generally observed on the posterior surface of the bladder, provided the latter be in a contracted state; these folds are expanded as the bladder enlarges, and thus they serve to accommodate the serous membrane to the varying conditions of the bladder without stretching or extending the former—a purpose which peritoneal folds or ligaments in general are intended to answer.

The superior fold or ligament extends from the summit of the bladder to the posterior surface of the recti muscles, and is partially reflected over the remains of the urachus and hypogastric arteries. This fold rather consists of three folds which diverge below and converge towards the umbilicus; they present a falciform appearance towards the abdomen, particularly when the bladder is contracted. In the fœtus these superior folds, particularly the lateral, are very distinct, as they each contain the umbilical artery. The urachus, which is in the centre, is also at that age very distinct though shorter; its vesical end is often pervious for about an inch: it is always closed before it arrives at the umbilicus, it then becomes filamentous, and is soon lost on the umbilical arteries.

The second medium of connexion between the bladder and the parietes of the pelvis is the vesical fascia, the reflections of which constitute the true ligaments of the bladder. The vesical is the internal lamina of the pelvic fascia reflected from the latter at the upper border of the levatores ani muscles: it covers the internal surface of this muscle on each side, and descends as low as a line drawn from the inferior border of the symphysis pubis to the spinous processes of the ischia. On this level it is reflected on the prostate gland and on the sides of the bladder, and posterior to this organ on the rectum and on several of the pelvic vessels and nerves. The anterior or vesical portion of this fascia is distinct and strong, and forms a pouch on each side of the bladder which assists in closing the pelvis; posteriorly this fascia is thin and cellular, being perforated by several vessels. Its anterior reflections constitute the *true anterior ligaments* of the bladder, which are described as arising from the lower margin of the pubis on either side of the symphysis, then passing backwards and upwards on the upper surface of the prostate gland, and expanding on the anterior region of the bladder; many of their fibres become continuous with the muscular fibres of the bladder. A depression exists between these two ligaments, along which the dorsal veins of the penis run from beneath the arch of the pubis to the side of the bladder in their course to the internal iliac veins, in which they terminate. The fascia, however, is not deficient in this depression between these ligaments, but is continued from one to the other so as to line this hollow and to cover the upper surface of these veins. The anterior ligaments present a smooth concavity towards the abdomen or pelvis; their perineal or inferior aspect is convex, and has inserted into it the posterior lamina of the inter-osseous or triangular ligament of the urethra.

The true lateral ligaments of the bladder are also two in number, one on each side; each is continuous with the anterior, and is formed by the reflection of the vesical fascia from the internal surface of the levator ani muscle to the side of the prostate gland, and of the bladder immediately above and outside the vesiculæ seminales. The pelvic and vesical fasciæ will be more particularly noticed in the article Pelvis.

Lastly, the bladder is retained in situ by the attachments of the cervix; these take place not only directly by the ligaments which have been just described, but also indirectly through its connexion to the urethra and of the latter to the pubes through the medium of the triangular ligament of the urethra. This ligament, for a fuller description of which we refer to the article Perineum, is a strong aponeurosis intimately connected to the rami of the pubes and ischia, and there continuous with the obturator fascia of each side. It is strong, tense, and unyielding, and closes all the anterior portion of the inferior orifice of the pelvis; it is perforated by a small opening, through which the urethra passes about an inch inferior to the bony edge of the pubes; the edges of this opening are continued on the urethra both towards the perineum and towards the pelvis. The process which extends in the former or inferior direction is lost on the bulb of the urethra, while that which extends in the posterior or superior direction, and which is more distinct and strong, encompasses the membranous part of the urethra, (which, while in situ, is very short,) and is then inserted or becomes continued into that reflected portion of the vesical fascia which forms the true anterior and lateral ligaments of the bladder; thus the commencement of the urethra, the prostate gland, and the neck of the bladder, which must be nearly synonymous with the prostatic portion of the urethra, are all retained in a nearly fixed position, and the continuity of the different aponoreuses in this region serves to afford mutual strength and general security.

The bladder, notwithstanding the foregoing connexions, is subject to displacement. In the male this occurrence seldom happens, although in some cases of very large inguinal or scrotal herniæ this viscus has been gradually drawn into the sac, in consequence, most probably, of adhesion between it and the omentum or some other of the protruded parts. We have already mentioned how a portion of the lining membrane may become protruded between the muscular fasciculi and form a sac which may increase to a considerable size, and extend into some new and even remote situation. In the female the bladder is very liable to partial pressure as well as to displacement, owing to different conditions of the uterus, such as retroversion, inversion, and prolapsus.

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(R. Harrison.)

BLADDER, ABNORMAL ANATOMY OF THE URINARY.—Under this denomination it is proposed to include all variations from the natural condition of the organ, whether the particular variety be a congenital vice of conformation or a consequence of extra-uterine disease.

In the following synopsis may be seen the several affections included, as well as the order in which they will be described in the present article.

- Changes . .
  - Congenital . .
    - Numerical . . . . .
      - Absence.
      - Plurality.
    - Of conformation . .
      - Septa.
      - Extrophy or extroversion.
      - Persistance of the urachus.
  - Acquired . . .
    - Of conformation . .
      - Sacculi or cysts.
      - Capacity, *increase of.*
      - *decrease of.*
      - Introversion.
    - Of position . . . .
      - Herniæ, *inguinal.*
      - *femoral.*
      - *perineal.*
      - *vaginal.*
    - Of structure . . . .
      - Inflammation with its consequences.
      - Idiopathic softening.
      - Rupture.
      - Fistulæ.
      - Hæmorrhage.
      - Fungoid tumours.
      - Varices.
      - Scirrhus.
    - Of function . . . .
      - Paralysis.
      - Spasm.

To some persons, the introduction of two functional diseases, paralysis and spasm, in an article on pathological anatomy, may appear objectionable; but as they are sometimes consequences of structural change, we hold that we have a perfect justification for their appearance.

CONGENITAL CONDITIONS.

Numerical changes.—Absence.—Among the single organs of the body, one degree of numerical diminution only is possible, namely, their absence. Such an anomaly, if we except true cases of monstrosity, should be extremely rare, and indeed it is so; for as all unique portions of the organization are called upon to perform functions, to which they are more or less exclusively devoted, it is rarely that any other can supply their place, and in consequence, when the organ is wanting, the function is also wanting.

There are upon record a certain number of instances of absence of the urinary bladder; in some of these cases the ureters have been found to terminate directly in the urethra, in others they have been inserted into the rectum, in others they have communicated with the vagina. Of the first species we have the following examples: Lieutaud * mentions the case of a man, aged thirty-five, in whom the ureters, the capacity of which was much augmented, terminated immediately below the pubis near the orifice of the urethra. Binninger* describes the case of Abraham Clef, in whom there was no urinary bladder, and the ureters opened upon the urethra. A stylet, introduced into the urethra, passed alternately into the one and the other ureter; the ureters were afterwards separated from the kidneys, and the stylet, introduced in the opposite direction, met with no obstacle to its passage into the urethra.

Of the second species we have, in the seventh volume of the Philosophical Transactions, the history, given by Richardson, of a lad residing in Yorkshire, who lived to the age of seventeen, without ever having passed urine through the urethra, and who had still enjoyed good health. The only inconvenience he suffered was a consequence of the passage of the urine into the rectum, by which a troublesome diarrhœa was kept up. Camper† speaks of five similar cases, one of which was that of a female. Klein‡ also speaks of a case. In the Nov. Acta Acad. Nat. cur. ann. i. obs. 38, there is another in which "ureter in rectum intestinum insertus fuit." And in the Hist. de l'Acad. ann. 1752, n. 4, there is one de-

* Hist. Anat. Med. Liber primus. Obs. 1361.

* Obs. Med. 24, cent. 2.

† In Mem. pour le Prix, &c. 8vo. edit. tome v. p. 9.

‡ Rachit. congenit. Nov. Eph. Ac. Nat. Cur. vol. i. obs. 38.

scribed under the head: "Uretra in intestinum patens."

Of the third species, cases are cited by Haller* and by Schrader.† In these cases there was no other malformation. In the foregoing enumeration we have purposely avoided the introduction of cases of general monstrosity in which the urinary bladder was absent.

Plurality.—There are upon record a certain number of cases in which two or more urinary bladders are said to have existed. Of these some appear to me to have been cases in which the plurality was maintained merely because the organ was divided into compartments, either as a consequence of arrested development or of the formation of pouches, by the protrusion, or hernia of the mucous membrane of the organ. The following case related by Blasius belongs, I apprehend, to the former species. A person died phthisical, having a "double bladder." When the external surface was examined, it appeared to be an unique organ, but upon being opened a membranous septum was discovered, by which the organ was divided into two distinct cavities. The narrator adds, that by dissection he separated the one from the other, so that the longitudinal septum was formed by the parietes of the two bladders, which were in contact, and had become united the one to the other. There is a case of a similar nature described by Bromfield; and many more are recorded by Morgagni and others.

We know of no instance in the human subject, with the exception of that related by Molinetti,‡ in which a plurality of urinary bladders distinct from each other existed. In this case there does not appear to have been any thing abnormal in the organisation except in so far as concerned the urinary organs. "A woman had five urinary bladders, as many kidneys, and six ureters, two of which were inserted into a bladder which was much larger than the others!! the remaining four ureters terminated in as many small bladders, which poured their urine by particular canals into the larger bladder." Another but less carefully described case of the same kind is mentioned by Fantoni, in his Anat. Corp. Hum. diss. 7; and in the Acta Physico-Medica Academiæ Cæsareæ Nat. Curios. vol. i. obs. 83, may be found a well-marked case of duplicity of the urinary bladder described by Zuinger, whose account is accompanied by a plate, which perfectly confirms the description; but this case occurred in an ox.

Septa.—Occasionally, within the cavity of the bladder, more or less perfect septa are found, by which that organ is divided into two or more compartments. This condition is met with or occurs under two very different circumstances: in one it is a congenital affection, and this it is our business to consider in this section; in the other it is produced by and is not an uncommon consequence of retention of urine during extra-uterine life. In the description of these two very dissimilar affections much confusion has occurred, in consequence of an almost universal impression that they were similar the one to the other. If the theory of the eccentric development of organs, proposed by Geoffroy St. Hilaire, and extended by M. Serres, be admitted, all difficulty in explaining this seemingly singular congenital phenomenon vanishes. M. Serres conceives that he has triumphantly established the fact, that the hollow organs, which are single and placed on the median line, are composed of two moieties, primitively distinct and separate; so that according to him, at a certain period of uterine life, there exist two aortas, two basilar arteries, two superior cavæ, and so on. Now if there exist two vaginæ, two bladders, two uteri, at a certain epoch of embryotic life, the evolution of these organs should necessarily present three successive periods: a first, characterised by their duplicity and their complete isolation; a second, by their mutual approach and union upon the median line; a third, by their complete fusion, which constitutes their permanent condition in man and the mammalia. We can therefore conceive that at the moment of the second period, when the two primitive organs are united, the parietes of both being entire and in contact on the median line, there will be a perfect septum separating the one organ from the other. At the commencement of the third period in the process of development, the septum is destined to disappear, the two cavities merge into one, and the work of development in the organ is complete. Now, in the evolution of all the organs, development may be arrested at any period of its progress: it may be arrested before the organs come into contact, in which case there would be two bladders; it may be arrested after they have formed a junction, in which case a complete septum would exist, as in the case described by Blasius; or the check may not occur until a greater or less portion of the septum shall have disappeared.

To distinguish the congenital affection which is a consequence of arrested development, from the acquired affection which is an extra-uterine disease, and is commonly an effect of retention of urine, is not difficult. In the former we shall always find that the entire of each pouch is invested by a layer of muscular fibres; in the latter, it will be found that

* Element. Physiologiæ, vol. vii. p. 297.

† Nov. Ephem. Acad. cur. Nat. vol. i. obs. 38, et die 42, obs. 68. [The Editor has in his possession the preparation of a female fœtus which lived some days, where the ureters opened through the abdominal parietes on each side of the pubic region in the form of little pouches or sacs, in which was a continuation of their lining membrane. The urine, as it distilled from the kidney, accumulated in each of these sacs (in very small quantity, as they were incapable of containing more than a drop or two,) prior to its oozing out upon the raw cutaneous surface. This latter was deficient of cuticle for a surface about an inch and a half in diameter; the pubic bones and the inferior fourth of the recti and tendinous expansions of the obliqui were absent. There was also only about an inch of large intestine (cœcum).—Ed.]

‡ Dissert. Anat. Pathol. lib. vi. cap. 7.

in one of the two compartments no such muscular investment is present.

Extrophy or *extroversion.*—Extrophy of the bladder was, up to a comparatively late period, almost universally regarded as a hernia of that organ; and it was not until about the middle of the last century, and after Tenon had dissected two such cases, that this opinion was shown to be erroneous.* Tenon discovered that there was a complete "absence" or destruction of the whole of the anterior parietes of the bladder; and that the tumour which is found at the hypogastrium is only the posterior parietes of this sac, with the "trigone" pushed forward by the abdominal viscera, as if for the purpose of blocking up the opening caused by the deficiency of substance below the umbilicus. On the surface of the tumour which is there presented, and at its inferior part, we see the urine almost continually exuding through two holes, pierced in the centre of two small nipple-like eminences, which are the orifices of the ureters. The insertion of these conduits of the urine at the inferior part of the tumour indicates that the portion of the bladder, which appears upon the exterior, is precisely that which, in the natural state, is found most deeply situated in the pelvic cavity, the internal surface of the posterior and inferior portion of the organ. The researches of anatomists have most positively confirmed these indications, by shewing that in extroversion of the bladder the anterior part of this organ is more or less completely wanting, and that the posterior part is pushed from behind forwards, through the large opening which results from this absence, causing a "*hernia*," either between the two pubes and the two recti muscles, or, which is very rare, only between the latter, the mucous membrane being presented externally. By this displacement the external posterior surface of the bladder forms a concavity in which some portions of the intestinal tube may be impacted, as in a true herniary sac, especially when the abdominal muscles and the diaphragm are strongly contracted. The volume of the tumour is on this account variable, not only as between one subject and another, but in the same subject at different ages. Thus in new-born infants only a slight projection is presented: the tumour may not occupy a larger space than from half an inch to an inch. In adults it may project to the extent of two or more inches and present a transverse diameter of four or five. The tumour is then smooth and frequently appears divided into two lobes.

When extroversion of the bladder exists, the umbilicus commonly is, as in the embryo and the young fœtus, not far removed from the symphysis pubis, nor consequently from the vesical tumour. The umbilicus is almost always found immediately above the tumour. Sometimes, however, the superior extremity of the latter is observed beyond the umbilicus, which is then entirely concealed; and in consequence of this circumstance, some author have believed that the umbilicus was not present in infants affected with extrophy, and they have drawn from this fancied absence physiological consequences as erroneous as the facts upon which they were based are groundless.

This affection was until recently supposed to occur only very rarely in the female; this opinion, however, is incorrect. In many of the cases on record the sex is not specified, and it is not improbable that many women may from a sense of shame be desirous of concealing such a disgusting deformity. Even with these reasons why the cases should be less numerous, we have been enabled to collect twenty-one examples. In women the affection does not produce so much derangement in the sexual functions as when it exists in man, by whom, the penis being almost constantly deprived of urethra, fecundation must be almost impossible. In the other sex, on the contrary, the vagina being ordinarily free, though more or less contracted, coitus may have place, as in a well conformed female, and fecundation may follow, as in the case detailed by Drs. Huxham and Oliver and Mr. Bonnet, of a woman who lived at Lantglasse near Fowey;* and that of Thiebault, in which the delivery occurred through the perineum. Among the anatomical varieties by which it is accompanied, none are more singular than that mentioned by Bartholin,† in which there was neither anus nor penis, all the ingesta returning from the mouth during forty years.

It has been over and over again maintained that this affection was incompatible with long life. The child of which Highmore speaks‡ was ten years old, and in good health; the case of which Montagne speaks§ was at the time a person of thirty; that of Flajani ‖ was seventy. Baillie,¶ Mowatt,** Innes,†† and Labourdette,‡‡ all describe the cases of adults. Quatrefages §§ describes the cases of a person of forty-nine and of another of forty-six.

Most authors who have written on this subject have strenuously maintained the constancy of the separation of the bones of the pubis. Duncan, even in spite of the case of Mr. Coates, with the details of which he was familiar, retained that opinion apparently unshaken. We are in possession of the particulars of cases in which no such separation existed, recorded by Coates,‖‖ Denman, Roose,¶¶

* Acad. des Sciences, 1761, tom. cxiv. in 12mo. p. 67.

* Phil. Transact. vol. xxiii. 1723, p. 408, 413, and vol. xxxiii. p. 142.

† Hist. Anat. cent. iv. hist. 30, p. 293.

‡ Disquis. Anat. part iv. cap. 7.

§ Acad. des Sciences, tome cxiv. in 12mo. p. 67.

‖ Malattie Spettanti alla Chirurg. 1786.

¶ Morbid Anat. p. 309.

** Mem. de Desgranges.

†† Arch. Génér. vol. ii. p. 286.

‡‡ Journal de Sedillot.

§§ Theses de Strasbourg, 4to. 1832.

‖‖ Edinburgh Med. and Surg. Journal, vol. i.

¶¶ De nativo vesicæ urinariæ invers. &c. p. 19.

Walther, and one of Quatrefages;* and there are still one or two others, about which some doubt exists. What proportion these cases would bear to those in which the separation was demonstrated, it is almost impossible to determine, because there can be no doubt that, of the numerous recorded cases, many of the descriptions appertained to the same individual, the total number of cases being in my opinion much less than is supposed. It is easy to explain how this source of error has been introduced. The unfortunate persons who are subjected to this infirmity are often objects of general curiosity. They wander from town to town for the purpose of obtaining a livelihood by exhibiting themselves to medical societies and to private individuals, and the history of a single person may thus be found repeated in the different periodicals of the same and even of different countries.

To determine the mode in which this vice of conformation is effected is very difficult. We cannot admit that Duncan's† explanation of the mode of its formation is correct, because it is opposed to every principle which we are accustomed to recognize as presiding over the developement of our organs. He attempted to prove that an obstacle to the expulsion of urine affords a satisfactory explanation of this phenomenon, and he believed that the bladder, by its distention, removes the bones of the pubis from each other, ruptures the hypogastrium, and then disorganises itself. We should have conceived that a very little reflexion would have removed from his mind so singular an opinion. The disease is almost always congenital, although during intra-uterine life the fœtus can have but little urine to void, and cannot, consequently, have a distended bladder. Duncan himself, however, strangely enough states the case of a little boy who was affected by the disease, although the urethra, placed in front of the root of the penis, strongly curved towards the anus, allowed of the easy passage of the renal secretion. And there are cases on record well authenticated, where no separation of the pubis existed. Isenflamm also states that the disease was manifested, in his experience, ten weeks after birth. The opinion of Duncan, therefore, cannot, it is apprehended, be sustained.

Those persons who believe this disease to be a primitive monstrosity are divided into two classes. The one suppose it to be merely an organic deviation, in which the urethra is placed above instead of gliding beneath the pubis. This, however, is not the prevailing doctrine; that which has obtained the most general currency is based upon the theory of arrested development. Supposing that the two moieties of the body do not, until late, meet upon the median line anteriorly, they say, if, by any cause, the sides of the hypogastric parietes cease to advance, the one towards the other, during their allotted time, the bladder will pass between them, and will soon lose its anterior moiety, supposing this moiety to be already formed, from whence the fungous state which it offers after birth. So powerful are the authorities by which this mode of explaining the phenomena is supported, so completely is it said by the ardent supporters of teratology to be in consonance with its principles, that it would appear to be almost heretical to support a somewhat different view of the subject taken by M. Velpeau. He believes that extrophy of the bladder is not simply owing to an arrested development, first, because in the normal state the bladder is neither split nor open, neither anteriorly nor posteriorly; secondly, because the pubic circle is completely formed before the bladder is perceptible; thirdly, because the aspect of the fissure that the urinary sac should present never exists; and, fourthly, because the theory in question has for its support only such analogies as do not appear to us to have been completely established. If an hypothesis be required, it appears to be more in consonance with observation to assume that this vice depends upon an alteration of the abdomen, either pathological or purely mechanical, contracted during embryo life. The parietes of the abdomen are extremely attenuated and fragile up to between the second and third months, and for some time beyond this the parietes do not acquire any thing like the density below that they do above the umbilicus. At this time the space is so small between the umbilicus and the sexual organs, that the smallest fissure may become the origin of a large ulceration, and such lesions are seen at all degrees. Indeed it is scarcely possible to set forth the variety of lesions to which the young fœtus is subject: fœtuses have been seen in which the parietes of the abdomen were alone destroyed. In one of three months the bladder was already comprised in such a perforation, and the borders of the whole were so jagged, thin, and unequal, that it could be referred to nothing else than a laceration. It is held in this place, therefore, that extrophy is frequently a disease, or the effect of a diseases, but not a monstrosity; an ulceration, a perforation of the penis or of the hypogastrium, being the common point of origin. The bladder is only secondarily altered. If the fœtus continues to live, the borders of the destroyed bladder are united to the circumference of the abdominal opening, or, at least, to the posterior surface of the remaining portion of the hypogastrium. The cicatrisation once effected, the rest is explained by the mucous nature of the organic septum, which occupies the place of the pelvic or abdominal parietes. The umbilicus may or may not be implicated in the loss of substance; the pubes, which are commonly destroyed, and not simply separated as has been believed, may be also preserved; and the vesical tumour may in some cases only occupy a space of a few lines, whilst in others it may implicate a great portion of the hypogastrium.

Those organs which are normally in relation with the pubis present certain anomalies in

* Theses de Strasbourg, 1832.

† Edinburgh Med. and Surg. Journal for 1805

extroversion of the bladder, which should be mentioned in this place. The ureters, of course, open immediately upon the surface of the body; the urethra no longer serves for the emission of urine, and is often incomplete. Commonly in woman it opens above the clitoris, in man above the penis. Occasionally the testicles do not descend. Meckel has remarked that there is commonly a separation of the two lateral moieties of the external genital organs, like that of the abdominal muscles and the pubis. It has been remarked by Duncan (loc. cit.) that this infirmity more commonly happens to the male than the female. Meckel doubts this proposition, and adds many cases to those cited by Duncan, in which the disease affected the female. Isidore Geoffroy St. Hilaire, who has carefully examined the recorded cases, which are now very numerous, supports the conclusion of Duncan: he says that of these one-fourth appertain to females, nearly two-thirds to males, and in the remainder the sex was undetermined. Extrophy of the bladder is a very serious affliction, because of the incontinence of urine which is its inevitable consequence, and the deformity of the genital organs by which it is constantly accompanied, and which, in man especially, very commonly occasions impotence. It constitutes a more serious disease in the male than in the female, for in the latter the external genital organs, except the want of projection of the pubic eminence, commonly suffer only slight modifications of form: the ovaries, the uterus, and their appendages may not even present any anomalies.*

Persistance of the urachus.—The last of the congenital malformations to which I shall allude is the persistance of the urachus sometimes even to adult age. For a considerable time much doubt was expressed whether the urachus was ever a canal, pervious from the bladder to the umbilicus; and it was not generally admitted until the fact had been repeatedly demonstrated by Haller and his pupil Norcen. In January, 1787, Boyer exhibited a bladder taken from a man aged thirty-six, in which the urachus formed a canal an inch and a half long, and containing twelve urinary calculi, each of the size of a millet-seed; and it was demonstrated that this canal was not a vesical sac or a prolongation of the mucous membrane. But these cases of persistance of the cavity of the urachus in adult or even in infant life are unquestionably extremely rare; and it is certain that a protrusion of the mucous tunic in the form of a canal at this point has been mistaken for the canal of the urachus; it is even probable that generally where the urine is prevented from escaping by the urethra, and where it escapes by the umbilicus, it results from the rupture of the species of hernia formed near the situation of the urachus by the mucous tunic of the bladder, and not from the dilatation of this membranous cord.

When this canal remains pervious only in a part of its extent, the anomaly is not indicated externally. When its cavity is preserved even from the bladder to the umbilicus, nothing marks its existence at the exterior if the urinary passages are unobstructed; in the opposite condition a very remarkable physiological anomaly accompanies it, and reveals the presence of the anatomical anomaly; it is the total or partial excretion of urine by the umbilicus, either constantly and from the moment of birth, which is the case when a vice of conformation or a disease prevents the urine from passing by its natural channel;* or temporarily, when the course of the urine, which was at first by the urethra, comes to be interrupted by any cause.

Sigismund König† relates the case of a woman in whom the urine, usually excreted by the urethra, passed by the umbilicus during some days in consequence of a severe labour; but this example and others which might be mentioned do not appear to possess the authenticity which is required to establish that this infirmity may be acquired. It is probable that many of these cases were simply a hernia of the mucous membrane of the bladder, such as occurred in the case detailed by Portal.‡

ACQUIRED CHANGES.

Sacculi or cysts.—A sacculated or encysted condition of the bladder is never a congenital vice of conformation of that organ, but an effect of disease. Sacculi may be produced by any thing which can oppose itself to the excretion of urine, or which may enfeeble the muscular tunic of the organ. In this way the urine becomes collected in the bladder, the parietes are distended, the internal tunic is forcibly applied upon the muscular coat, and if at any point this tunic be weakened, less resistance is offered, a separation between some of its fasciculi takes place to a sufficient distance to admit of the mucous membrane passing between them, and in this way sacculi may be formed.

This, however, is not the only way by which this state may be produced; in some bladders the muscular tunic is so developed, probably by irritation, that its fasciculi are grouped and a columnar aspect is produced, not very unlike to the appearance of the interior of the ventricles of the heart.

* For more minute details of this affection the reader may consult Blasius, part iv. obs. 6. Stalpart Vanderwiel, vol. ii. p. 56. Bartholin, cent. ii. hist. 65, the Edinburgh Essays, vol. iii. p. 257, the Journal Encyclopedique, August, 1756, the Journal de Médecine of Paris, t. v. p. 108, et t. xxvii. p. 26, the Memoirs of the Academy of Sciences of Paris, 1761, where we find an observation of Lemery made in 1741, and three facts observed by Tenon, also the second volume of Medical Commentaries by a Society of medical men at Edinburgh, p. 437, and the Memoirs of Duncan (Edinb. Med. and Surg. Journ. 1805), and Velpeau (Mém de l'Acad. Royale de Méd. tom. iii.)

* Littre, Mém. de l'Acad. des Sciences, 1701, p. 23. Sabatier, Traité d'Anat. t. ii. p. 402, et t. iii. p. 498.—Cabrol, Alphabet Anat. obs. 20. This case occurred at Beaucaire in 1550.

† Phil. Trans. v. 16.

‡ Mém. de l'Acad. des Sciences, 1769.

Certain portions of the parietes of the organ are in such cases unprovided with the muscular fibre necessary to enable them to offer the usual resistance, and a similar effect is produced to that which I have already described, the mechanism being somewhat different.

These sacs may attain great size, even superior to that of the bladder itself; commonly the point by which communication with the bladder is maintained is only a narrow neck, and in consequence of this circumstance the organ has occasionally been described as double, triple, and so on. It is always easy to determine whether it be really so or not, first, by examining the parietes of each, and, secondly, by ascertaining the points at which the ureters are implanted. In the first case we shall find only one of these compartments invested by a muscular tunic: in the second an ureter has never yet been known to penetrate directly the adventitious cavity.

There is scarcely any point of the surface of the bladder in which such a state may not be produced, but there are certain regions where the affection is much more frequently met with than others. They are most commonly formed at the lateral parts, or at the summit, near the insertion of the urachus. Occasionally many of these sacculi are found in the same bladder.*

A species of sacculi or appendices may, however, be produced by an extension, at a given point, of the whole of the vesical tunics; and even these may be a consequence of retention of urine, but more frequently of the sojourn of a stone, which forms a cell. Some examples of this species are given by Morgagni.† A woman, two years before her death, introduced into the urethra "a long hair pin;" this instrument slipped from her grasp and passed into the bladder, where it became arranged transversely, so that whilst the point rested upon the left, its head rested on the right side of the organ. The head became incrusted with calcareous matter; a stone of the size of a nut was thus formed, which was contained in a quadrilateral sac produced by the extension of the whole of the tunics of the bladder.

Cells or cysts may be otherwise formed at the expense of the vesical parietes. Calculous concretions may be formed in the kidney, and may pass unobstructed through the ureter into the bladder; but if the magnitude of the stone be disproportioned to the capacity of the canal of the ureter, it may sojourn at any point of the continuity of this canal, or at the point where it terminates in the bladder. If also the calculous matter be abundant in the urine, it will be deposited upon this nucleus, which will more or less rapidly augment in volume, and will be impacted at or near the point where it may have acquired this augmentation. The first author who speaks in a clear and precise manner of this affection is the celebrated Pierre Franco.* Since Franco, it has been described by by many others, particularly by Alexander Monro† and Houstet.‡ The existence of this affection is certainly not frequent, but its occasional occurrence is amply proved: formed in the way I have described, these calculi occasionally glide between the mucous and muscular tunics of the organ by means of an opening which they form at the point where the ureter obliquely pierces the bladder, instead of entering the bladder by the natural channel. The volume of these cysts is never very considerable, for such calculi do not acquire anything like the volume of those which are commonly found moving freely in the cavity of the bladder. The reason of this is obvious; they are not exposed to the action of any considerable quantity of urine, and they cannot consequently receive a large accession of calculous matter. Covillard§ and Garengeot‖ have seen them of the size of a hen's egg, but such cases are rare. Commonly they are very little removed from the insertion of the ureters. The reason of this is not, however, that which was assumed by Littre,¶ because the contraction of the muscular fibres is made towards the fundus, and that in consequence the calculus would be forced towards that region, but by reason of the resistance offered by the membrane of the cyst by which they are surrounded.

CHANGES OF CAPACITY.

The bladder may suffer certain modifications of capacity as consequences of disease. It may become so distended as to contain nine pounds of urine (in puella pro hydropica habita, Kœnig)** novem *chopines* ab ischuria, La Motte;)†† or even twelve pounds, Felix Pascal: or it may become so diminished that its volume shall not exceed that of a small walnut. In 1764, M. Portal found at Montpellier, in the dead body of a woman aged sixty, the bladder so small that its volume did not exceed that of a hazel-nut.

Decrease.—In persons who pass urine frequently, the bladder is small; still more so in those whose kidneys do not perform their functions properly. It is small in those cases of irritation by which frequent contractions are excited. Lithotomists have frequently remarked that in calculous patients the bladder closely embraced the stone. Morgagni,‡‡ in opening the body of a girl of fourteen, found the bladder adherent to the parietes of the abdomen immediately above the pubis, and so contracted around a needle, which had been introduced sixteen months before her death, that this viscus could scarcely have contained anything more.

* Heister.

† De Sed. &c. ep. xlii. art. 18.

* Traité des hernies, chap. xxxi. p. 107, Lyon, 1561.

† Essays and Observations of the Medical Society of Edinburgh, vol. vi. p. 257.

‡ Mém. de l'Acad. des Sciences de Paris, ann. 1702.

§ Obs. 11.

‖ Mém. de l'Acad. de Chir., t. i. p. 411.

¶ Mém. de l'Acad. des Sciences, an 1702.

** Lith. spec. Epist. 11.

†† Traité des Accouchmens, Obs. 44.

‡‡ De Sed. ep. xlii. art. 20.

The bladder is also very small in cases of incontinence of urine and in vesical fistulæ.

Increase.—The volume of the bladder augments when the whole or a great portion of the urine is retained in its cavity, and under the opposite conditions to those which have just been named. To such an extent may this increase proceed, that it may be mistaken for ascites.* Inflammation of the bladder commonly accompanies its excessive dilatation, but many circumstances related by Morgagni and others prove that this viscus may be considerably distended by urine without becoming inflamed. It may, however, lose its contractile power, and the assistance of art may be necessary for the evacuation of the urine. A fact stated by Mauchart† shews that a man had ischuria, which had commenced four days before he was sounded. Some days after this he died; the bladder was found inflamed in different points. It was entirely empty and yet very voluminous, without being contracted as it is commonly after death.

Introversion.—Among the acquired changes of conformation of the urinary bladder, there is one which may be termed introversion. In this affection, which is rare, the superior portion of the organ is so depressed as to be brought near to its neck, to project into the urethra, and in woman to make its appearance at the external orifice of that canal. Chopart ‡ relates from Percy the following observation:—The patient was an abbess aged fifty-two, in whom the fundus of the bladder was impacted in the neck, having also passed along the urethra, and forming at its external orifice a tumour of the volume of the eye of a pigeon, red, fleshy, unequally tumefied, which, when pressed upon with the finger, returned into the canal and reappeared without any violent exertion. An analogous case occurred to Foubert.§ The patient died, the body was examined after death, and it was found that the posterior and superior region of the bladder was depressed into the form of a cone whose apex had penetrated the neck of the bladder, a portion of ileum about six inches long being lodged in this depression.

When, in the female, the summit of the bladder is engaged in the neck, the simple inspection of the tumour, its increase after walking or in consequence of a fit of coughing, its disappearance with compression, are symptoms sufficient to enable us to recognize the disease. Those aged persons whose bladders are very capacious, and who are become feeble, are most subject to this affection, which is produced by the pressure which the other viscera exercise on this organ.

Hernia.—The absence of information in old authors on the subject of hernial displacement of the urinary bladder induced an opinion which was current for very many years, that the affection we are about to consider was of extremely unfrequent occurrence. This, however, is an erroneous opinion, for the experience of modern times has demonstrated, that though less frequent than hernia of the intestines or of the epiploon, cystocele is not an unfrequent disease.*

The inguinal ring, the crural arch, the perineum, and the anterior walls of the vagina may become the seat of a hernia of the bladder. At whichever of these points the disease may be manifested, the bladder, fixed deep in the pelvis and hidden behind the pubes, is never completely displaced; only prolongations of the organ can pass these several points. It must be at once evident that besides the dilatation of the opening through which it passes, there must be a great increase in the capacity of the organ itself, and a great relaxation of its parietes, occasioned most commonly by retention of urine, or by a habit of only rarely attending to a desire for its evacuation. Whether the protrusion occur at the one or the other of the several regions I have named, there are certain general characters by which it may be more or less readily detected. We shall find a soft tumour, accompanied by a fluctuation which is as much more sensible, and which acquires a volume as much more considerable as the time which may have elapsed without an evacuation of urine is greater. This tumour may be easily lessened by compression, but the reduction is immediately followed by an urgent desire to pass the urine.

This species of hernia is only partially covered by peritoneum. Dominique Sala is, according to Bartholin,† the first person who mentioned this peculiarity. The reason of this circumstance is obvious: when the bladder is distended, it is raised to the level of the crural arch and of the inguinal ring; it pushes before it the peritoneum, and insinuates itself between the peritoneum and the abdominal muscles. If at this time a violent effort determine the escape of the corresponding part of the organ by one or other of these openings, it is the anterior, superior, and lateral part of the organ which will be presented, and this is the portion which is without a peritoneal investment; so that at this time the herniæ we have described are completely deprived of a sac. It usually happens, however, that the posterior portion of the organ soon follows, dragging with it the peritoneum by which it is covered; this portion in turn drags down that which is in the vicinity of the ring; and in this way a hernial sac is formed, ready for the reception of the intestine or the omentum. This is the reason why a hernia of the bladder is so frequently accompanied by an intestinal or omental hernia.

* Chopart, Smellie, Black.
† Ephemerides Acad. Nat. Cur., cent. ix. obs. 41.
‡ Traité des Maladies des Voies Urinaires, t. i. p. 399. Edit. 1830.
§ Mém. de l'Acad. de Chir., t. ii. p. 36.

* For a confirmation of this opinion, see Blegny, Traité des Hernies, 1688; Mery, Mém. de l'Acad. des Sciences, 1713; Petit, même ouvrage, 1717; Le Dran, Garengeot, and La Faye. Heister and Platner, Instit. Chir. J. G. Gunzii, Obs. an. Chir. de Hernia, Lipsiæ, 1744; Monro, Levret, Sharp, Pott, Scarpa, Lawrence, and others.
† Hist. Anat., cent. xviii.

It does not appear to be well established whether a primitive hernia of the bladder occurs in the direction of the inguinal canal, or whether it escapes directly through the aponeurotic opening of the external abdominal muscle, though the latter opinion is the most probable. It has been remarked in some cases that the spermatic vessels were external to the hernia.

In consecutive vesical hernia an intestinal hernia primarily exists; the intestine pushes before it the peritoneum which surrounded the ring, and in proportion as the hernia increases in volume, does the sac augment, the peritoneum in the neighbourhood of the ring is drawn down, and, as a consequence, that which invests the posterior surface of the bladder, which in its turn is also drawn down, if, on the one hand, the adherence of the peritoneum to the bladder be sufficiently strong, and if, on the other, the latter organ be voluminous and susceptible of displacement. The primitive perineal and vaginal herniæ are similarly situated as to the non-existence of a hernial sac, and of the existence of consecutive hernia in these situations we have no record.

The species of vesical hernia which is most commonly seen is the inguinal; the tumour is usually confined to the groin, but it may descend into the scrotum, gliding along the spermatic cord.*

Hernia of the bladder at the crural ring is very rare. It presents the same characters and is subject to the same complications as that which occurs at the inguinal ring. Its form and its seat only are different; it is developed at the same point as a merocele, and like it takes a globular form.

Vesical hernia at the perineum is an extremely rare disease, and for some time was supposed to occur exclusively in pregnant women, but the observation of Pipelet is conclusive as to the possibility of its existence in man. In these cases a portion of the bladder passes between the fibres of the levator ani muscle, and it is presented in the form of an ovoid tumour placed at the side of the anus. In each of the three species of hernia which we have described, the bladder suffers certain changes of form: it is contracted at the level of the opening through which it passes, and is again dilated below this point. This circumstance has been observed by Keate, Pott, and Bertrandi. Sometimes even calculi have been found in the displaced portion of the bladder.†

Few occasions have occurred of observing hernia of the bladder through the vagina. In this affection the fundus of the bladder depresses the anterior parietes of the vagina, and forms a round projection, which is frequently visible externally when it passes the level of the orifice of the vulva. The disease is usually developed during pregnancy when pressure is made by the distended uterus upon the neighbouring organs; but cases have occurred at an advanced period of life. Of all the species of hernia of the bladder, that by the vagina occasions the most pressing symptoms, and these symptoms are principally owing to the deviation which is produced in the canal of the urethra, which is drawn downwards and forward by the fundus of the organ, so as to prevent the passage of the urine along it. In this way a complete retention of urine is produced, together with tension, pain and augmentation of volume in the abdomen, agitation, sleeplessness, sympathetic irritation of the heart and the brain.

Considerable doubt has usually been expressed, whether hernia of the bladder is susceptible of true strangulation; whether the sensibility of this organ is of the same nature as that of the intestines, and whether its constriction might give rise to similar symptoms. In the case described by Plater,* strangulation does, however, appear to have occurred, but the symptoms which he detailed were not well marked. The symptoms given by J. L. Petit † do not appear sufficient to enable us to distinguish strangulation where the bladder is implicated from that in which the intestine suffers. Hiccup, says Petit, precedes vomiting in hernia of the bladder, while in intestinal hernia the latter precedes the former symptom. If strangulation should occur, the method of relief proposed by Durand, viz. to empty the tumour by puncture with a trocar, appears rational.

Inflammation.—Inflammation of the bladder may be produced by a variety of causes: among them we may mention external violence, incised wounds of the organ, contusions on the hypogastric or perineal region, concussions of various kinds, the bladder being distended, the compression consequent upon pregnancy, upon a laborious accouchement, upon the use of the forceps, upon the presence of a pessary or a hernial displacement; the presence within the organ of foreign bodies, whether introduced from without, generated within, or derived from the kidneys, distention consequent upon retention, and the use of cantharides and certain other diuretic medicines. It may also be communicated to the bladder by neighbouring organs, such as the kidneys, the urethra, the prostate, the uterus, and the rectum. It may be developed during the progress of acute gastro-enteritis, may succeed to certain articular inflammations, to certain cutaneous affections, and to the suppression of a hemorrhoidal or menstrual flux.

The affection is more common in men than in women, and at the approach of age than at any other period of life. Boisseau describes the disease in a male child of two years old; Lesaive in a female child of two years and a half. Acute inflammation commonly affects at the same time more than one of the vesical tunics; there are, however, on record two cases in which acute inflammation was limited to

* Pott's Surgical Works, vol. i. case 26.
† Pott, loc. cit.

* Obs. lib. iii. p. 830.
† Traité des Mal. Chir. tome ii. p. 368.

the peritoneal tunic of the organ.* Dr. Baillie suggests, as a reason for such limitation to this particular tunic, the quantity of cellular tissue interposed between the serous and muscular tunic, and the laxity of their connection the one with the other. Chronic inflammation is frequently confined solely to the mucous tunic of the organ.

Acute cystitis may terminate by complete resolution; it may cause a secretion of pus, which is either diffused in points over the greater part or even the whole of the surface of the organ, or circumscribed under the form of abscess; may produce ulceration, may terminate in gangrene, or it may assume a chronic form.

If death supervene during the intensity of acute inflammation, we find the mucous membrane strongly injected, patches being presented of a brownish colour, commonly in the vicinity of the neck and fundus of the organ; nor does it appear that the occurrence of such patches in these situations can be attributed to the irritation occasioned by the prolonged contact of acrid urine. At other times the mucous membrane is thickened, and the veins much dilated; pus is disseminated over the surface, or collected into foci; patches of false membrane are extended over portions of the organ or floating in the contained fluid, and gangrenous points are presented; these points may only affect the mucous tunic, or they may affect the entire thickness; it is sometimes studded with small ulcerations, which are more or less concealed by folds of the membrane, and not unfrequently it is softened. Usually the organ is very much contracted, so much so as to present only a very small cavity. This effect is induced by the contraction of the muscular fibres which is excited by the extension of the irritation from the mucous membrane.

When the disease terminates by *resolution*, ordinarily, in a short time, all trace of the existence of the affection disappears. In certain cases, however, where it has existed long, the parietes of the bladder have been found slightly thickened; one or more branches of veins have become varicose and consequently more apparent. If the disease have had a still longer existence, we may find the mucous membrane thickened; but this effect is more frequently manifested in the muscular tunic.

When a purulent secretion is produced, pus is found diffused through the substance of the parietes, more particularly, however, in the cellular and muscular layers, and an appearance of hypertrophy is here produced; or it is poured out upon the surface of the mucous tunic. Occasionally, but unfrequently, abscesses are formed between the tunics, but these are commonly a consequence of wounds or contusions of this organ, or of the operation for stone. In such cases the abscess may open itself on the external surface of the bladder, or upon the interior. Sometimes it is presented upon the sides of the rectum, but according to Chopart it is usually in the neighbourhood of the neck of the organ that suppuration commences. When an abscess opens upon the internal surface of the bladder, the pus passes out, mixed with the urine; in such cases we discover after death more or less extensive and profound fistulous openings, which are sometimes surrounded by varicose veins, sometimes covered by dark grumous blood, extravasated from the small vessels which ramify on them: they all exhale a fetid odour.

Ulceration of the bladder as a consequence of acute inflammation is unfrequent; indeed, of this affection there are only a very small number of cases on record. When it occurs, it is commonly caused by the opening of a purulent collection upon the mucous surface of the organ. A case, detailed by Marechal in the 28th vol. of the Recueil Périodique des Travaux de la Société de Médecine de Paris, is the best marked case of the affection with which we are acquainted. It was that of a hussar, in whom the affection appeared to be brought about by a violent attack of gonorrhœa: the patient died on the fifth day. Upon an examination of the organ after death, it was found rather contracted; though not filled with urine, its parietes sustained themselves; it contained eight ounces of a greyish thick matter: the mucous membrane was extremely thick, and covered by a glutinous stratum. It presented, however, many ulcerations of varied extent; the parietes of the organ were six lines in thickness.

Occasionally it happens that inflammation of the mucous membrane of the bladder proceeds to gangrene, which is characterised by a change in the volume of the hypogastric tumour, supposing the organ to be distended, the cessation of pain, the sudden prostration of the vital powers, the complete suppression of the flow of urine, the excessive distention of the bladder and the ureters, and sometimes by the escape of urine by the umbilicus;* more frequently, however, by the rupture of the organ and the extravasation of its contents into the abdominal or pelvic cavity. In cases which are a consequence of retention, the gangrenous points may be presented either at the fundus or at the summit of the organ;† but most commonly the affection is a consequence of the irritation or pressure made upon the bladder by a foreign body, and in these the point implicated is that upon which the body has directly exercised its influence. When we examine the mucous surface of an organ so affected, we discover that the disease exists under two distinct forms, the diffuse and the circumscribed; but the latter of the two forms is not often witnessed except as a consequence of local violence. Dr. Carswell, however, bears testimony to its occasional existence; he states that the congestion is extreme, and often accompanied by hemorrhage, which gives to the

* See Baillie, Wardrop's edition, vol. ii. p. 259, and Nauche, Maladies des Voies Urinaires, p. 27.

* Walther, loc. cit.

† See Hunter, Hey, and others.

membrane a uniform deep red colour. Moreover, dark brown or black patches are found to occupy portions of various extent of the mucous membrane, which, as well as the submucous tissue, is easily torn, and other portions of this membrane are seen partially detached, and converted into a soft spongy substance having a strong gangrenous odour. In the circumscribed form of gangrene, we sometimes see a number of black eschars, which are soft and nearly putrid : sometimes greyish pulpy points are presented, which appear to implicate only the mucous tunic, but in the greater number of cases we see the different stages of their progress; they are at first whitish, they then become yellowish, grey, slate colour or brown, and blackish ; but these changes are much more marked when the organ has been subjected for a short time to the action of the atmosphere. Where the whole of the parietes are involved, the eschar is characterised by a greyish slaty tint. These eschars are frequently confounded with the violet or brown portions or patches by which they are surrounded; these latter are simply extreme congestion, bordering, it is true, upon gangrene, but susceptible of being restored to a healthy state, whilst the death of the other points is inevitable.

When acute inflammation affects the muscular tunic of the bladder, the organ usually becomes strongly contracted, and the parietes present an appearance of considerable thickening; at the same time pus is commonly infiltrated through the tissue, or it is circumscribed into the form of abscess; the tunic is then of a dark red colour and strongly injected. In a case which was seen by Gendrin, where the patient refused to submit to the operation for stone, the internal tunic was ulcerated and of a red-brown colour; the muscular tunic was more than half an inch in thickness, and contained two abscesses, each of the size of a small nut. Velpeau saw in a patient who had died of a diarrhœa, the bladder reduced to the size of a small fist; it was hard and elastic; its parietes were more than an inch thick. In the cases described by Martin Ripaux, Molat, Maret, and Berard,* the mucous membrane was not in any way implicated, the hypertrophy being entirely limited to the muscular tunic. In these cases the bladder was reduced to very small dimensions, and the mucous coat made many projections into the cavity; the summit of these projections was red and vascular. It is not unlikely but that it may be owing to the excess of extent of the mucous over the contracted muscular tissue in such cases, that the former so easily becomes engaged in the formation of appendices. The muscular tunic may be much increased in thickness in the absence of acute or even chronic inflammation of the organ; any irritation by which a frequent contraction of the organ may be excited will most probably produce a great increase of thickness of this tunic. Among these causes we may range the existence of fistula or calculi in the organ. Sometimes the thickening is limited to the mucous tunic. M. Portal, in examining the bladder of an old man, the parietes of the organ being eight or nine lines in thickness, found the internal tunic like cartilage, and that this was the only tunic which had acquired an increase of substance; the peritoneal tunic was in its natural state, the muscular scarcely apparent. Chopart made a similar remark with regard to the bladder of an adult. Morgagni mentions a like case.*

Instead of either of the modifications which have been described, acute cystitis may degenerate into a chronic form of the disease. This form of the affection does not commonly succeed to a single and simple attack of the acute affection; almost always there will have been sundry recurrences of the acute form before this degeneration takes place. Most frequently chronic cystitis occurs without having the acute disease as a precursor, and it is upon chronic inflammation that extensive disorganisations of the various tissues of the economy are mainly dependent; and the alterations of texture in the parietes of the bladder are, therefore, most commonly produced by its agency.

In such cases we may see the mucous membrane of an uniformly dark violet colour, thickened and unyielding, the organ so contracted as to present only a very small undilatable cavity, incapable of containing more than a few drams of fluid. Fungous excrescences are sometimes developed upon its internal surface, especially in the vicinity of the neck. In some cases ulcerations will be found to have destroyed the muscular tunic and penetrated to the peritoneum; in others, the mucous follicles present a most exaggerated development, communicating to the membrane a considerable increase of thickness, but without change of colour. In other cases, the muscular tunic having acted with increased energy, its fibres have become more voluminous and project into the interior of the organ in the form of columns, between which the mucous membrane sometimes forms what is termed 'hernia.' But the more ordinary consequence of chronic inflammation of this organ consists in the thickening and more or less uniform induration of the vesical parietes. The tissue of the bladder is then converted into a homogeneous, lardaceous substance, similar in appearance to that of the unimpregnated uterus; the vessels which surround the organ are dilated, varicose, and form on the external surface considerable plexuses, which attest the long existence of its excitation, and the continuance of the afflux of blood of which it has been the seat.

Ulceration as a consequence of chronic inflammation of the mucous membrane of this organ is unfrequent, but as an effect of the presence of a calculus is less so. Of the first species a description, with a fine plate, is given by Baillie, of a case in which the mucous

* Vide Transact. de la Société Anatomique.

* Ep. 41, art. 6.

membrane covering the posterior and superior surface of the bladder was destroyed; a similar case is given also, with a plate, by Walter; another is described by Paré.* A case is described by Jalon,† in which the whole of the muscular tunic was as well displayed as if it had been prepared by dissection. There are several well-marked cases on record in which this species of ulceration, consequent upon chronic inflammation, had extended to the whole of the tunics and caused an extravasation of urine. These ulcerations are sometimes very numerous, almost like erosions, and they are often concealed between the folds of the relaxed mucous membrane, so that they are not discovered until the membrane is stretched out. Under the influence of either acute or chronic inflammation, pseudo-membranes are now and then generated upon the surface of the mucous tunic of the organ, usually during the suppurating period of the affection. These membranes are either adherent or free, and they are sometimes expelled through the urethra: this circumstance has induced a belief in an often repeated error, that the mucous tunic of the bladder may be entirely detached and expelled with the urine; among those who have perpetuated this error are Ruysch and Morgagni.‡

Under the influence of chronic, and much more rarely of subacute inflammation, the mucous membrane of the bladder furnishes in large quantity a species of muco-purulent fluid. This affection was termed by Lieutaud § catarrh of the bladder. When the affection presents the subacute form, it is frequently extended to the other tunics of the organ; and if we examine it after death, we shall find similar appearances to those which have been described in speaking of acute inflammation. When the disease is chronic, it often lasts for years, and we then discover little change of colour in the membrane, but we find it often prodigiously thickened, the vessels varicose, and the cavity much contracted.

Idiopathic softening.—During the progress of some acute and many chronic diseases, the mucous membranes of the body not unfrequently become softened, in the absence of inflammatory action in their tissues: in the bladder, however, this state has been only very rarely witnessed. This fact is important, especially when we reflect upon the functions of the organ and the great variations to which the liquid of which it is the reservoir is exposed. M. Louis,‖ in a very careful examination of five hundred bodies, found this idiopathic softening in only two cases. In these the mucous membrane in a great portion of the fundus of the organ was reduced into a "*mucilage*" possessing a consistence little if at all superior to that of mucous pseudo-membranes. The membrane thus altered was pale, even at the limits of the softening; there was no injection or vascular congestion at any point of the bladder, nor in any of the vessels which existed on the exterior of the organ; neither was there at the interior any erosion or other product of inflammation. It is probable that it is in such cases that even a careful introduction of the sound has occasioned a perforation of the bladder; it may be as well to mention that no true friability of the mucous membrane, so commonly found in inflammation, existed in these two cases; the tunic was soft, as if formed of a viscid jelly, but it did not present either the redness, the infiltration or the induration by which inflammation is characterised. So general is the opinion that softening is uniformly a consequence of inflammation, that in taking an opposite opinion it appears to be incumbent upon us to state our reasons for doing so. Although the differences which may be remarked between softening of this tissue and its inflammatory condition appear to be very great, yet able observers have still believed themselves justified in regarding all softening as the result of inflammation. It is so important to have correct ideas on this point, that we ought here to refute the reasoning by which that opinion is supported. It is stated that softening of mucous tunics is, in the greater number of cases, united to evidently inflammatory alterations; such as a more or less vivid redness of the softened parts, together with an injection and tumefaction. This assertion is gratuitous; for in all cases where the condition has been well observed, softening in the first degree has scarcely ever been united to unequivocal inflammatory alterations. In the second degree of softening, the existence of inflammation is frequently demonstrable.

It is especially by studying the anatomical characters of the early stage of softening that we shall be enabled to establish the non-existence of inflammation; we may go farther, and say that the characteristics of softening are directly opposed to those of inflammation. In the latter we find injection and vascular congestion; in the former the capillaries have disappeared;—in inflammation, thickening, and at first augmentation of density in the membrane, which becomes rugous to the touch; in softening we find thinning and diminution in the density of the tunic, with loss of its tenacity, and it is soft to the touch;—in inflammation we observe specific inflammatory products at the surface and in the substance of the tissue; in softening a diminution and absence, then a total extinction of this secretion, which is not only not augmented at the commencement of the disease, as in the first stage of inflammation, but is immediately diminished.

Inflamed tissues at a certain epoch do, it is said, become soft and friable; why should it

* Lib. xvii. ch. 59.

† Eph. Nat. Cur. D. 11. an 11. obs. 129.

‡ A case of the kind is detailed by M. Destrées in the Journal Général de Médecine, tome lxviii. p. 206.

§ Méd. Prat. tom. i.

‖ Repertoire Général, tome iv. part i. Faits relatifs aux lésions de la membrane muqueuse de la vessie.

not be so in mucous or villous tissues? Although this reasoning proves nothing,—for we cannot judge from analogy in a graphic science like pathological anatomy,—yet it is the simple expression of the truth, because it is certain that mucous tunics are softened by inflammation, but this softening does not resemble in any thing the idiopathic softening.

Rupture.— Rupture of the bladder is a more frequent occurrence than that of the œsophagus, the stomach, or the intestines; it occurs sometimes without external violence, simply by a distention of the organ, from a prolonged retention of urine; most commonly, however, it is produced by a violent blow, or the passage of the wheel of a carriage over the hypogastrium, or the violent efforts to which a woman is subject during the pains of labour, the bladder being in a state of plenitude. In the first case, the rupture usually occurs near the insertion of the ureters or the neck of the bladder, because it is at these points that the distended organ usually begins to thin and tear. In the second case it is usually at the inferior fundus of the organ that the rupture is found.

We have already pointed out the circumstances under the influence of which the bladder may be ruptured, and we have stated that the extravasation of urine by which it is followed is commonly productive of fatal consequences.

In a certain but small number of cases, the patient is able to resist the inflammatory symptoms which are developed, urinary abscesses are formed, which may open either in the vicinity of the umbilicus, at the hypogastrium, in the inguinal region, in the vagina, at the perineum, or in the rectum, and a fistulous canal is organised.

Fistulæ. — Fistulous communications between the bladder and the vagina or intestines are commonly the result of purely mechanical causes, such as the action of a calculus which may destroy the recto-vesical septum, the action of a foreign body introduced into the anus and penetrating the bladder, the lateralised or recto-vesical operation for stone, the operation of lithotrity, or as a consequence of the pressure produced by the head of the child in parturition. Vesico-intestinal fistulæ sometimes establish a communication between the bladder and the ileum or colon,* and then the summit of the bladder is usually the seat of injury. When the communication is established between the bladder and the rectum, the posterior surface of the bladder is commonly implicated; the neck of the bladder may, however, be similarly affected, and then it is commonly owing to the action of a calculus or other foreign body directed upon this portion of the vesical parietes. At other times the lesion succeeds to chronic inflammation, or to a cancerous ulcer which has extended from the rectum to the bladder; and then the perforation almost always exists near the neck of the latter. The communication of the intestine with the bladder is sometimes established without abscess, without external inflammation. Sometimes the urine does not escape by the rectum, while fæcal matter and flatus pass from the rectum into the bladder.

* London Med. Journal for 1784, part 2; Edinburgh Medical Commentaries, vol. ii. part 2.

Ordinarily, however, the urine passes into the rectum and often causes diarrhœa; the bladder, distended by intestinal gas, forms a sonorous and painful tumour at the hypogastrium.

Vesico-vaginal fistulæ are sometimes though rarely occasioned by the action of a foreign body introduced into the vagina; sometimes they are the result of the progress of a uterine cancer; but in general the cause by which they are produced is a laborious accouchement, during which the head of the infant has remained long in the passage, and has by its pressure determined gangrene of the vesico-vaginal septum. The accident may be produced by the imprudent use of instruments; but this is a rare occurrence, perhaps for the reason that instruments are comparatively unfrequently employed. In a few days the eschars which are the result of that gangrene are thrown off, and the consequent loss of substance may then be demonstrated. We find that these fistulæ have not always the same form, the same direction, nor the same extent. In some cases they are longitudinal, at other times transverse; in others their form is irregular. The extent of the loss of substance is also very variable: sometimes the fundus of the bladder is extensively destroyed, so much so as to allow of the opposite parietes of the organ being implicated in the opening, and forming a true vesico-vaginal hernia. When the disease is a vesico-umbilical fistula, the communication is with the summit of the bladder, and is commonly caused by a dilatation of the urachus or by the prolongation of the mucous membrane of the bladder, which is directed along the cord produced by the conversion of the urachus and the vessels by which it is accompanied into a cellular structure.* In either case the disease is almost invariably a consequence of the existence of some obstacle to the passage of urine along the urethra.

The pubic and inguinal fistulæ succeed to an accidental opening of the bladder, which, having formed a tumour in those regions, has been taken for an abscess, a hernia, or an encysted tumour; to wounds, to ruptures, puncture, or incision of the organ; to its perforation in consequence of a purulent focus being in contact with its parietes, or by a suppuration in these parietes themselves. All fistulæ of the bladder have this in common, that the urine escapes from their orifice drop by drop, almost continually, often without contraction of the bladder, and without the patient having wished to urine; sometimes it escapes in greater quantity during those motions of the body which excite the pressure of the abdominal muscles. In consequence of the habit which the bladder has acquired of remaining

* See Van-der-Wiel, Littre, Tenon, and Roux.

empty, it almost always becomes contracted; in all cases its capacity is considerably diminished.

Hæmorrhage from the bladder.—Instead of the mucus which is furnished by the mucous membrane of the bladder when in the state of health, it may be the seat of a sanguineous exhalation. When a sanguineous fluid is excreted from the bladder, it does not of necessity follow that it has proceeded from the mucous membrane of that organ; it may be brought by the ureters from the kidneys. When the fluid is produced within the vesical cavity, the mode of production is not uniform: it may be a simple exhalation from the mucous membrane, or it may be a consequence of the destruction of the mucous membrane by gravel, by a calculus, or by a foreign body introduced from without; or it may be a consequence of the rupture of varicosed vessels. Blood is, however, rarely exhaled at the internal surface of the bladder, unless the mucous membrane be in a state of structural disease: yet this exhalation is occasionally manifested as a result of intemperance, or the use of certain irritating diuretic medicines, concussions of the pelvis; in woman the sudden suppression of the menstrual evacuations, and in man of a hemorrhoidal discharge.

It is very difficult, and sometimes even almost impossible to determine whether the fluid be derived from the kidney or from the bladder; and to arrive at any thing like a sound opinion, it is necessary to consider carefully all the circumstances of the case. Much as it has been relied on, we cannot consider as a symptom peculiar to vesical hæmorrhage, the mixture of blood with the urine, and the sensation of burning and weight behind the pubis, at the perineum, and at the extremity of the penis; for these symptoms occur in some cases where there is no effusion of blood, and in others where the blood has arrived from the kidneys.

It is also very difficult to decide as to what is the exact state of the bladder, even when we are convinced that the blood discharged from the urethra is derived from that organ. Chopart found the vesical mucous membrane, more particularly at the fundus, studded with red points in an old man subject to hæmaturia; these points appeared to him to be vascular orifices.* In other persons who have suffered from a similar affection, different kinds of fungus have been discovered on this membrane. A man, aged seventy-three, had hæmaturia, but there was no stone in the bladder. As there was no appearance of disease about the kidneys, it was attributed to the rupture of some varicose vessels in the neighbourhood of the neck of the organ. After death the bladder was found of great size, and within the trigone was a fungous rounded ulceration, six lines in diameter, surrounded with varicose veins and small fungous excrescences. Ordinarily, however, gravel or calculi appear to be the exciting causes of this disease.

* Loc. cit. tome ii. p. 52.

Fungous tumours.—The information which we possess on the subject of fungous tumours or excrescences of the bladder is not sufficiently precise to enable us to attempt to arrange them according to their variety in structure or development. The tumours which we propose to describe are those which do not implicate the whole of the parietes of the organ, but project into its cavity under the form of more or less perfectly pediculated excrescences. We are, therefore, under the necessity of considering simultaneously all those tumours, however variable in structure, which come under the definition which we have given. Many eminent pathologists have expressed an opinion that these tumours are always directly connected with the prostate; but their occasional existence in the female sufficiently proves that this opinion is incorrect. In 1750 Mr. Warner removed from the bladder of a woman a fungous tumour of the shape and size of a turkey's egg. Walter* details the case of a young woman in whose bladder he discovered what he calls a *polypus*, which extended itself nearly to the external orifice of the urethra. It is true that these morbid products are more commonly seen at the fundus of the bladder than at any other point of its surface, and it is equally true that a large number of those affections which are described as fungous tumours of the bladder, were really morbid products arising from the prostate, which will be described in the article on the PROSTATE GLAND.

The circumstances necessary for the development of these tumours are unknown, but it would appear that the larger number occur under the influence of irritation produced by calculus. Ordinarily only one of these tumours is found, and then occasionally it attains a considerable volume. Fabricius Hildanus† describes one of the size of a hen's egg, and weighing two ounces. Zacutus Lusitanus‡ found one of these polypi of the size of a goose's egg, and so hard that he could not cut it with scissars. There are, however, many examples in which a greater number existed, but in these cases the tumours are usually small. Chopart§ describes a case which he examined at the Hotel Dieu, in which there were found three tumours, the largest being nearly as large as a cherry. Ludwig describes a case in which he found two of small size in the bladder of a man of sixty-three. Desault once saw the whole of the cavity of the bladder studded with small "fungous tubercles." Lobstein‖ has seen three, and Bartholin¶ two. This affection is rarely seen before adult age. Morgagni** has never seen them in infants or in young persons.

* Einige Krankheiten d. Nieren und Harnblase, 4to. Berlin, 1800, tab. iii.
† Cent. ii. obs. 65.
‡ Prax. Med. Ader. lib. ii. obs. 71.
§ Loc. cit. tome ii. p. 77.
‖ Diss. de Dysuriâ.
¶ Anat. cent. ii. Hist. 52. p. 243.
** De Sed. ep. lxvi. art. 12.

Deschamps, in 1791, whilst removing a calculus from the bladder of a boy of twelve years, discovered on the anterior and lateral parietes of this organ, a small fungous tumour of the size of a cherry, which projected to the distance of half an inch from the surface. Baillie, in his Morbid Anatomy, has given a plate of a polypus of the bladder which he found in a child, and which not only occupied the whole of the cavity of the organ, but sent prolongations into the urethra.

The structure of these tumours is very various; the greater number appear to possess a fibrous structure, others present a white homogeneous, lardaceous texture at their base, whilst their free surface may be red, vascular, or even carcinomatous; sometimes they are hard and almost cartilaginous in their whole thickness; at others they present calcareous concretions.

Around the points from which these tumours arise the bladder is ordinarily thickened and indurated: this is, we apprehend, a consequence of the continued irritation which has attended their development.

Varices. — The arteries and veins of the bladder present numerous ramifications in the cellular stratum, which separates the muscular from the mucous tunic of this organ; and in the neighbourhood of its neck they form an immediately apparent plexus. This vascular structure in inflammation becomes so marked that the mucous membrane appears to be entirely formed of these vessels. Though it might be expected that during the existence of inflammation these vessels would become more dilated and manifest, yet it cannot be regarded as a true varicose condition, there being neither partial dilatations nor projecting indurations like those which characterize varices situated in other parts of the body. Bonnet describes the case of a man, who during life had suffered from the ordinary symptoms of stone, but in whose bladder no stone was discovered after death. The veins around the neck of the bladder were varicose and very much distended with blood.* Morgagni discovered in the body of a man aged sixty, in which the tunics of the bladder were very thick, large vessels creeping along its internal surface around its neck. They were so distended with blood, that at first he almost believed they were hæmorrhoids rather than parallel vessels.† A similar case is described by Chopart, in a calculous patient. There cannot, therefore, be any doubt that such a disease may exist. It appears to occur principally when the parietes of the bladder are thickened, when it contains calculi or fungi, or when its neck or the prostate are tumefied. It is not unfrequent in old men and in inhabitants of warm countries. The disease has much analogy with hæmorrhoids, and appears to increase under similar sources of irritation. It may contract the neck of the bladder and so cause retention. These veins may become inflamed and produce divers alterations in the mucous tissue. This membrane may be thinned, take a fungous appearance, give rise to hæmorrhage, in fact assume somewhat of an erectile character.

* Sepul. lib. iii. sect. 25, p. 263.

† De Sed. ep. 63 art. 13.

Scirrhus and Cancer.—Cancer primitively affecting the membranes of the bladder is an extremely rare disease. Chopart relates only one example of the kind.* Desault describes another;† Lallemand another.‡ Soemmering appears to doubt whether the disease ever exists.§ In each case to which I have alluded the disease occurred in man, and I know of no case on record in which the disease has primarily existed in the bladder in woman. In the whole of the cases the disease was characterized by lancinating pains behind the pubis, and by the emission of particles of decomposed animal matter; these were the only symptoms which were calculated to excite suspicion as to the nature of the disease. In every one of them the scirrhus was situated in the fundus of the bladder and near its neck. The whole of the membranes at that point were transformed into a scirrhous lardaceous substance, varying in thickness from two to four inches, and in two cases the tumours were somewhat funnel-shaped, the internal surface of which was unequal, bristling with very projecting vegetations of a cauliflower character. Most commonly the affection is the result of the extension of a similar disease from the uterus or the rectum, and the symptoms by which the affection might be announced are confounded with those of the affection of the uterus or of the rectum. This affection may exist with dilatation or contraction of the cavity of the organ, with or without ulceration, with or without hypertrophy of the muscular tunic. When derived from the uterus, the affection is manifested at the fundus of the organ, and a communication is usually soon brought about between it and the vagina, and as a consequence the urine flows involuntarily from the vulva. When derived from the rectum, the fundus is commonly affected; and in either case these productions are manifested within the vesical cavity under the form of fungous vegetations.

Paralysis.—The bladder is not an exception to the rule, that "all parts of the body may become unfit for the functions which they are destined to perform;" it may lose the faculty of contractility, which is indispensable to the accomplishment of excretion. Under many circumstances it may contract with too much force; in a still greater number its contractility is enfeebled and ultimately destroyed. Apoplexy, hemiplegia, paraplegia, concussion

* Traité des Maladies des voies urinaires, tome p. 466. Edit. de 1821.

† Traité des Maladies des voies urinaires, 3d edi p. 177.

‡ Obs. sur les maladies des organes genit urinaires, p. 8.

§ Traité des Mal. de la vessie et de l'urètre, trad de H. Hollard, 1824.

and inflammation of the brain and its meninges, extravasations within the cranium, and still more concussion and inflammation of the spinal marrow and its membranes, and extravasations within the spinal canal, consequences of contusions of this part; the excessive distention of the bladder by the accumulation of urine within its cavity, either in consequence of neglecting to attend to the desire of excretion, or because the want has been resisted by false delicacy, or because an obstacle exists at the neck of the bladder or in the urethra; inflammation of the mucous membrane, especially when it affects the neighbourhood of the neck of the organ; the sudden cessation of articular pains, inflammations of the skin or of the genital organs; exasperated gastro-enteritic affections which are accompanied by affections of the brain and the spinal marrow; abuse of the sexual organs;—these are among the circumstances under the influence of which the bladder loses partially or completely its contractility.

We must not therefore regard all cases of paralysis of the bladder as evidence of feebleness, nor confound the inability to contract, with those mechanical obstacles which, acting on the bladder or the urethra, oppose the excretion of urine. We should always endeavour to ascertain whether there be a real paralysis of the bladder in cases where the brain or the spinal marrow is injured, and where there is detected abuse of the sexual organs. When retention is primitively the effect of inattention to the desire to pass urine, there is only excessive distention of the muscular fibres, but that distention is formidable in its effects; for no fact is better established than this, that when we submit muscular fibre to excessive distention or contusion, it loses the faculty of contracting. Again, in cases of inflammation of the bladder, there is less of paralysis than a suspension of contraction in the muscular tunic, in consequence of the proximity of the mucous tunic, which by reason of its inflammatory state becomes still more painful when its tissue is ruffled by contraction. There may, however, be atony or even a real paralysis of the muscular tunic during the existence of inflammation of the mucous tissue.

It is important to distinguish the case where paralysis is simple from those in which it is complicated by inflammation of the mucous membrane of the bladder or that of any other organ, and for that purpose it is necessary to analyse with care the symptoms. We must also bear in mind that from simple, complete, and primitive paralysis of the muscular tunic to inflammation of its mucous tunic, the interval is only very short, in consequence of the irritating impression which is exercised by the accumulated urine which has become much deteriorated in its qualities by its prolonged retention. From the time when paralysis is fairly established, the bladder is quite insensible to the stimulus of the urine—it is merely an inorganic sac, which may become enormously distended. Haller found in a drunkard the bladder so dilated that it was capable of containing twenty pounds of water.* Frank† saw a similar bladder which simulated ascites; he evacuated from it at one time twelve pounds of urine without removing all that it contained. William Hunter, in his Anatomy of the Gravid Uterus, plate 26, has given a fine representation of a bladder which extended as far as the xiphoid cartilage of the sternum.

This affection may, according to Baillie,‡ exist during two distinct states, one when the muscular tunic of the bladder has lost its contractile power, the other while that power is still retained. He adds, that after death these two cases cannot be distinguished the one from the other, but that by an attentive examination of the symptoms the existence of each may be recognised during life. It may be complicated with inflammation of the organ, and in this case rupture of the bladder may occur,§ to which may be added the case of the celebrated Tycho Brahe.‖ Zuber ¶ distinguishes this affection into that of the neck and that of the body, and this distinction is important, for the second being sometimes accompanied by a species of spasm or want of consent in the neck, a retention of urine must be the result, whilst the former occasions incontinence of that fluid.

Spasm.—Spasm of the bladder is an affection of frequent occurrence; it accompanies the various forms of cystitis, calculus, and often inflammation of the urethra. In fact it may be excited by any kind of irritation of the bladder or urethra, or by certain affections of the kidneys and of the rectum. It is not our purpose to consider in this place any other than what may be termed the idiopathic species of this affection. Hoffmann describes the case of a man who sank under the numerous and violent attacks of this disease, and in whom, after death, except in one particular, the bladder was found perfectly healthy; this was in the thickening and dilatation of its vessels, in which there was still much blood. Of course, although no anatomical lesion was found in this case, some irritation capable of exciting the spasm must have existed.

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* Elementa Physiologiæ, art. Vesica.

† Oratio de signis morborum ex corporis situ, partiumque positione patendis, Ticini, 1788.

‡ Path. Anat. chap. xiii.

§ See cases related by Ploucquet, Bibl. Med. Pract.

‖ Petri Gassendi Tychonis Brahei vita, Paris, 1654, in 4to. p. 206.

¶ Diss. de Morbis vesicæ.

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(Benjamin Phillips.)

BLOOD, (Gr. *αἷμα*. Lat. *sanguis*. Fr. *sang*. Germ. *Blut*. Ital. *sangue*). This is the title given to the peculiar fluid which carries into the living tissues of animals the materials necessary to the nutritive processes going on within them.

The physical qualities of this fluid vary extremely; among almost all the lower animals it is so far from resembling what we are accustomed to regard as essential to the blood in man and the vertebrata generally, that its nature is at first sight apt to be mistaken, and we cannot be surprised that the inferior tribes of creation should have been long supposed to be without blood. In the mammalia, birds, reptiles, fishes, and several of the annelida, the blood is of a red colour; among the whole of the invertebrata, a few of the annelida excepted, it is, on the contrary, nearly colourless; frequently it has a decidedly blue tint, and in many instances it is bluish, greenish, or yellowish. A celebrated chemist (Berzelius) has lately stated that the common fly (one of the insecta) had red blood in the head, and colourless blood in the other parts of its body. It is true, indeed, that if the head of one of these insects be crushed, a reddish fluid is forced out; but this is not blood; it proceeds from the eyes of the insect, whose blood, in the head as elsewhere, and among all the other species of the genus, as well as among the arachnida, crustacea, and mollusca, is almost colourless.

From these differences in the appearance of the nutrient fluid, the animal kingdom has been divided into *animals having red blood* and *animals having white blood*. But these modifications of colour are not perhaps of so much consequence as has commonly been believed, for they are met with among animals having in all other respects the most striking analogy one with another, as has already been seen in our particular article on the ANNELIDA.

The blood is an opaque, thickish fluid, of a specific gravity greater than that of water. In man its density varies from 1,052 to 1,057. It has a saline and rather sickly taste, and it diffuses a peculiar odour, which varies somewhat in different tribes, and occasionally in the different sexes of the same species. In all the vertebrata, it is, as we have said, red; but the shade of this colour varies in different animals, as it is familiarly known to do in the same animal, according as it is examined in its course to the tissues which it is destined to supply with nourishment, or after it has already traversed these, and is returning to the centre of the circulation; the colour, however, may be stated to be generally deep.

Examined by the naked eye, the blood appears to be perfectly fluid and homogeneous; but if it be spread in a very thin stratum upon the object plate of a microscope, and viewed under a lens having a magnifying power of between 200 and 300, it will be seen to consist of two distinct and heterogeneous parts, viz. a transparent yellowish watery fluid, and a number of solid corpuscles, of extreme minuteness, suspended in this fluid. To the fluid portion, the name *serum* is given; the minute corpuscles are spoken of as the *globules of the blood*.

The discovery of the globules of the blood is almost contemporaneous with that of the microscope; it is due to Malpighi and to Leuwenhoeck. A considerable number of observers have since engaged in the microscopical study of the blood; but it is to Hewson and to the Messrs. Prevost and Dumas that science is indebted for the most important facts and the best connected series of inquiries into the composition and qualities of this fluid.*

The form of the globules of the blood varies in different animals, but appears to be at all times essentially the same in individuals of the same species; this at least is the case if we except the first periods of their embryotic existence; for in the embryo the globules have been found to be different before the formation of the liver, from what they are after the development of this organ.

The globules of the blood of all the mammalia that have been examined are of a circular shape, whilst in birds, reptiles, and fishes, they are elliptical; in the invertebrate animals, however, they are again circular.

The whole of the microscopical observers of modern times are agreed in the above points; but they differ in opinion with regard to the nature of these bodies. This discrepancy, however, does not appear to us to be owing so much to any optical illusion to which the microscope exposes those who use it, as to the choice of objects made by the different observers. Too many of them have been satisfied with the study of the human blood, the globules of which are extremely small and always seen with great difficulty, whilst, had they made use of the blood of certain animals, as of the frog, or, better still, of the water-newt (*Salamandra cristata*), they would have escaped much of the uncertainty that surrounds their conclusions.

The globules of all animals having red blood are more or less flattened, and in the greater number of cases they resemble a small circular or elliptical disc. Leuwenhoeck was aware of this fact in reference to birds, reptiles, and fishes, but he believed that in the human subject and the other mammalia these bodies were spherical.† This error, which was sanctioned by Fontana and various others of the older observers, and has even very recently been adopted by Sir E. Home and M. Bauer,‡ was, however, completely refuted by Hewson, Prevost and Dumas, Hodgkin and Lister, Müller, &c.; my own observations also confirm the conclusions of these physiologists, and even go to prove that the globules of the blood in the invertebrata have the general form of flattened vesicles.

The greater number of observers appear to think that the whole of the globules of the blood of any animal are of the same dimensions. When blood in which these globules are very minute is examined, and a low magnifying power is employed, it is quite true that no perceptible difference in point of size can be detected; but by estimating the magnitudes of a great number of these globules comparatively and under a powerful microscope, I have satisfied myself that they differed in size in the same individual. Among the lower animals, the river-crab (*astacus fluviatilis*) for instance, it is by no means difficult in the same drop of blood to perceive globules of very different dimensions; and although this inequality is much less remarkable among the higher animals, I may affirm that it exists. Thus, in the same drop of a frog's blood, I have seen globules that differed from one another in the proportion of 39 to 45, without my being able to ascribe these variations of diameter to any circumstance connected with my mode of observing, or to any optical illusion: the globules were spread in a single layer upon the object plate, and so close together as to be exactly within the focus of the instrument. Their apparent diameters, I may state, were estimated by tracing, with the assistance of the camera lucida, the outlines of their images, upon a board eight inches distant from the eye-piece. I found corresponding differences of dimension among the globules of the human blood; in the same drop I have measured several which were to each other in the ratio of 112 to 140: in general, however, the differences are scarcely appreciable.

The globules of the blood appear to be identical in every part of the circulating system, and hitherto no difference in their size or shape has been detected in individuals of the same species, though of different ages and sexes.

It was long found a matter of considerable difficulty to determine the precise diameter of the globules of the blood; we consequently find marked discrepancies in the conclusions come to by different microscopists. At the present day, however, and since our means of observation have been improved, the estimates have become gradually less and less discordant, and therefore may be held worthy of the greater confidence.

From a very great number of measurements taken by means of the process of M. Amici (with the camera lucida), and under a magnifying power of 900, I have obtained as the mean term of the diameter of the globules of the human blood $\frac{1}{325}$ of a line (English,) or in decimal fractions 0,00030 of a line. But as I have already said, I have found considerable variety in the sizes of the globules; some, and these were the largest, were 35 ten thousandth parts of a line, and others, the smallest, no more than 28 ten thousandths of a line in diameter.

These estimates accord very nearly with the last admeasurements published by M. Dumas, and taken by a different method. He gives 31 ten thousandths of a line as the mean diameter of a globule of the human blood according to his latest observations.*

The conclusions come to by Dr. Hodgkin and Mr. Lister are also very nearly the same, these observers estimating the diameter of the

* Vide Hewson on the Blood, and Prevost and Dumas, Examen du Sang et de son action dans les diverses phenomenes de la Vie, in Biblioth. Univers. de Geneve, t. xvii.

† Philos. Trans. No. 165, 1684, p. 788.

‡ Ibid. 1818.

* Annales des Sciences Naturelles, tom. xii. p. 59.

globule of the human blood at 33 ten thousandths of a line. These dimensions exceed, it is true, the mean of the measurements I have taken, but they are still within the limits of the individual variations which I have encountered among these corpuscles; and as the physiologists quoted do not say whether their estimate was made from the mean of a number of observations, or from the measurement of only a few globules more apparent than the rest, it is impossible for me to determine whence this discrepancy in our conclusions arises, whether from actual varieties, from the manner of proceeding in determining the magnifying power of the microscope, or from an error in taking the limits of the image projected by the camera lucida.*

The observations made some twelve years ago by Messrs. Prevost and Dumas do not differ from the measurements already given. The diameters they then assigned to the globules of the blood, amounted to 33 ten thousandths of a line ($\frac{1}{150}$ of a millimetre); but the magnifying powers they at that time employed did not exceed 300, and consequently the difference between the diameter of a globule $315\frac{1}{100000}$ths of a line and one $367\frac{1}{100000}$ths of a line might fail to be detected; further, the errors which arise from the determination, always somewhat arbitrary, of the limits of the image, are sufficient to explain such slight differences as occur in the results of these very delicate observations. We must also add that Messrs. Prevost and Dumas at this time made use of a method, much less accurate than the camera lucida, for taking the apparent diameters of objects under the microscope, causing the image seen in the instrument with the right eye to coincide with the divisions of a scale placed laterally under the left eye. We therefore believe ourselves justified in the preference we accord to the more recent observations of these gentlemen.

The late Captain Kater, at the request of Sir E. Home, also made some observations with a view to determine the diameter of the globules of human blood, taking his measurements in the manner formerly employed by Messrs. Prevost and Dumas, but making use of a power not higher than 200, by which the chances of erroneous conclusions were greatly increased. His first observation, nevertheless, comes extremely near what we are inclined to regard as the truth ($22\frac{1}{10000}$ths of a line); a second observation, however, gives a much smaller diameter ($13\frac{1}{10000}$ths of a line), but it is possible that in this case the observer may have taken his measurements from a globule divested of its colouring matter, or perhaps from one of the albuminous globules which abound in the serum, and which are in fact very nearly of the dimensions indicated.*

Mr. Bauer and Sir E. Home had previously assigned $58\frac{1}{10000}$ths of a line as the diameter of these globules; but their observations having been made with the ordinary micrometer are necessarily defective, inasmuch as the globules placed upon this instrument, and the divisions drawn on its surface, can never be simultaneously in the focus of the object glass.†

Dr. Wollaston held that the globules of the human blood did not exceed $20\frac{1}{10000}$ths of a line in diameter, which is considerably different from our mean; and Dr. Young did not estimate them at more than $16\frac{1}{10000}$ths of a line.‡ It is also possible that both of these eminent individuals have measured the central nuclei of globules divested of their vesicular envelope. The results just specified having, farther, been come to by the aid of the *eriometer*, an instrument which we have searched for in vain through all the instrument-makers and collections of philosophical apparatus in Paris, and as we are altogether ignorant of the degree in which its indications may be relied on, we cannot discuss these conclusions with an adequate knowledge of the elements from which they are derived. As to the measurements published long ago by Jurine, they are so discordant that no confidence can be placed in them; the first diameter he assigned to the globules of the blood was $19\frac{1}{10000}$ths, the second $51\frac{1}{10000}$ths of a line.

From all that has gone before, then, and particularly from those researches which have been conducted under circumstances the most favourable to accurate conclusions, we may assume the mean diameter of the globules of the human blood to be about the $31\frac{1}{10000}$ths, or in vulgar fractions the $\frac{1}{325}$th part of a line.

Messrs. Prevost and Dumas have given the dimensions of the globules of the blood of a great number of other vertebrate animals; in these observations they employed the same means of estimating the diameters as in their earliest researches on the size of the globules of the human blood, so that to me their valuations appear to fall somewhat short of the truth. This slight presumed inaccuracy, however, scarcely detracts from the interest of the general results; for the measurements being all taken by the same means and therefore comparable one with another, are adequate to show in the clearest light the differences that occur in the dimensions of these corpuscles in different animals. The following is the table of admeasurements given by the physiologists quoted.

* Vide, Some microscopical Observations on the Blood, &c. in Philos. Mag. Aug. 1827.

* Vide Additions to the Croonian Lecture, Philos. Trans. 1818.

† Loc. cit.

‡ Young, Elem. of Med. Literature, 8vo. Lond. 1818.

NAMES OF THE ANIMALS.	Diameter of the globules in vulgar fractions of an English line.		Diameter of the globules in decimal fractions of an English line.	
MAMMALIA.				
Man *Canis familiaris, L.* *Sus scrofa, L.* *Mus ponellus, L.* *Mus avellanus, L.* *Lepus cuniculus, L.* *Erinaceus Europeus, L.*	$\frac{1}{430}$		0,000231	
Simia Sabæa, L.	$\frac{1}{305}$		0,000328	
Equus asinus, L.	$\frac{1}{421}$		0,000335	
Felis catus, L. *Mus musculus*	$\frac{1}{435}$		0,000220	
Equus caballus, L. *Equus hybridus, L.* *Bos taurus, L.* *Ovis aries, L.*	$\frac{1}{508}$		0,000196	
Antelope rupicapra, L.	$\frac{1}{553}$		0,000181	
Capra hircus, L. *Cervus elaphus, L.*	$\frac{1}{730}$		0,000104	
AVES.	Great diam.	Small diam.	Great diam.	Small diam.
Strix flammea, L. *Columba domestica, L.*	$\frac{1}{190}$	$\frac{1}{430}$	0,000526	0,000231
Didus ineptus, L. *Anas boschas, L.*	$\frac{1}{200}$	id.	0,000500	id.
Phasianus gallus, L.	$\frac{1}{205}$	id.	0,000488	id.
Pavo cristatus, L.	$\frac{1}{215}$	id.	0,000463	id.
Anas anser, L. *Corvus corax, L.* *Fringilla carduelis, L.* *Fringilla domestica*	$\frac{1}{218}$	id.	0,000458	id.
Parus major, L.	$\frac{1}{251}$	id.	0,000316	id.
REPTILIA.				
Testudo terrestris, L.	$\frac{1}{132}$	$\frac{1}{195}$	0,000757	0,000512
Colubra berus, L.	$\frac{1}{152}$	$\frac{1}{254}$	0,000657	0,000316
Anguis fragilis, L.	$\frac{1}{167}$	$\frac{1}{292}$	0,000598	0,000342
Coluber Razomouskii	$\frac{1}{152}$	$\frac{1}{254}$	0,000658	0,000316
Lacerta grisea, L.	$\frac{1}{167}$	$\frac{1}{282}$	0,000598	0,000354
Salamandra cincta, L. *Salamandra cristata, L.*	$\frac{1}{80}$	$\frac{1}{142}$	0,001132	0,000704
Rana bufo, L. *Rana esculenta, L.* *Rana temporaria, L.*	$\frac{1}{114}$	$\frac{1}{190}$	0,000877	0,000526
PISCES.				
Gadus lota, L. *Cyprinus phoscinus, L.* *Cobitis barbatula, L.* *Muræna anguilla, L.*	$\frac{1}{190}$	$\frac{1}{313}$	0,000526	0,000319

From my own observations I am inclined to think that the globules of the blood of the frog have a mean long diameter of about 96$\frac{1}{10000}$ths of a line; but the individual differences observable among the several globules ranged between 87$\frac{1}{10000}$ and 100$\frac{1}{10000}$ths of a line. In the blood of the water-newt (*Salamandra cristata*) I have obtained in my measurements of the long diameters of the globules the following extreme individual varieties: minimum 106$\frac{1}{10000}$ths of a line, maximum 127$\frac{1}{10000}$ths.

The outline of the globules in all the vertebrate animals is extremely well defined; but they are readily deformed or put out of shape. Even during life their pressure mutually, or the pressure they experience between the currents in which they move and the parietes of the vessels against which they are driven, suffices to alter their form; they are then frequently seen to become elongated, to bend, in a word, to alter their figure considerably; but they are extremely elastic, and readily and soon resume their pristine state.

Among the invertebrate animals the globules of the blood are much less regular in their forms. Their surface is uneven and tuberculated, like that of a raspberry; their contour is extremely variable; they change their figure with the greatest facility, and their size is considerable. In the blood of the river crab for example (*astacus fluviatilis*) I have found their mean diameter to be $70\frac{1}{10000}$ths of a line. Several, however, were measured which were no more than $67\frac{1}{10000}$ths of a line across, and others which were as much as $72\frac{1}{10000}$ths. In the oyster I have detected still wider differences in the size of the globules of the blood. In the same drop of this creature's blood I found some globules $60\frac{1}{10000}$ths, others only $54\frac{1}{10000}$ths, and some no more than $40\frac{1}{10000}$ths of a line in diameter.

It is well ascertained that the blood differs during the earlier periods of embryotic existence from what it is in after life. Messrs. Prevost and Dumas have shown that the globules of the blood in the chick in ovo are circular at first, and only become elliptical at the period when the liver is developed.* And M. Prevost found that in the fœtus of the goat these corpuscles were at first the double in diameter of those in the adult animal.†

The structure of the globules of the blood, as well as their magnitude, has been a subject of great variety of opinion. The differences in the conclusions, however, appear to me to depend principally on the circumstances in the mode of experimenting. Della Torre and Styles believed that the globules of the blood were perforated in the centre and fashioned like rings. When they are examined with lenses of low magnifying power, they look like small black points; when viewed under an instrument rather more powerful, they assume the appearance of a white circle with a black point in its middle; this is evidently what has given rise to the opinion we have quoted; but the appearance in question by no means depends on the existence of a central hole in the globules; it is merely the effect of the light; for by using a magnifying power of 300 or 400, the central point assumes the appearance of a luminous spot, and by varying the position of the globule, as well as the direction of the rays of light, the observer may easily convince himself that the globules are entire. Hewson, to whom we are indebted for so many good observations on the blood, was the first who arrived at accurate conclusions in regard to its globules. He considered them as flattened vesicles, in the interior of which there is a central corpuscle or nucleus. The accuracy of this opinion, which has been maintained in our own day by Messrs. Prevost and Dumas and others, has been called in question by Dr. Hodgkin and Mr. Lister; nevertheless to me it appears to be founded on unquestionable data. In studying the blood of the Reptilia, in which the globules are of very considerable magnitude, Messrs. Prevost and Dumas have even seen the outer envelope of these corpuscles tear, and expose the central nucleus naked. In 1826 I myself observed that by acting with a little weak acetic acid on the globules of the blood, previously placed on the object-plate of a microscope, they are very speedily stripped of their envelope, and their central nucleus is obtained isolated.* Professor Müller,† who does not appear to have been acquainted with this observation of mine, has lately arrived at the same conclusions, and has varied his experiments in such wise as to place the results that follow from them in the clearest possible light. I shall only further add that at the moment of writing this article I have again assured myself of the facts as stated, by subjecting the blood of the river-crab and that of the frog to renewed examination.

The existence of a solid, white, central nucleus in the globules of the blood consequently appears to me to be completely demonstrated; and there is, further, every reason to believe that the peripheries of these corpuscles are membranous vesicles formed of the matter which gives the blood its peculiar colour, or rather that they enclose this colouring matter between their inner surfaces and the central nuclei. This vesicular part of the globule is very elastic: whilst engaged in examining the capillary circulation in the lungs of the water-newt, Messrs. Prevost and Dumas frequently saw the globules change their figure under the pressure of the moving column of fluid, and mould themselves in some sort upon the parts that opposed their advance, but they resumed their original form the instant they escaped from the influence of the unequal pressure.‡ In general the tegumentary vesicle is collapsed upon the central corpuscle, and thus forms a kind of disc of different degrees of thinness near the edges, but plump or filled out towards the middle. By observing the globules of the blood of the frog and water-newt in different positions, the existence of this central tumidity may be so positively ascertained as to be beyond the reach of farther doubt; but in the human blood, the globules of which are extremely small and almost entirely occupied by the central nucleus, it is more difficult to be satisfied of its occurrence; and Dr. Young has even been led to think that these globules are discs concave on both sides, an opinion which has been revived and advocated anew by Dr. Hodgkin and Mr. Lister. The ap-

* Mem. sur le developpement du Cœur, &c. Annales des Sciences Nat. 1 Serie., t. iii.

† Ann. des Sciences Nat. t. iv.

* Mem. sur les tissus: Ann. des Sciences Natur t. ix.

† Observations sur l'analyse de la Lymphe d Sang, &c. Annales des Sciences Naturelles, 2 Serie Zoologie, t. i. p. 559.

‡ Vide Magendie, Physiologie, t. ii.

pearance or disposition of the globules in question, when it occurs, seems to me to depend on an alteration of these corpuscles. In examining the blood of frogs diluted with thin syrup, the globules occasionally appeared to me to become turgid, but not to be distended equally in every part; the exterior vesicle then remained attached to the centre of the internal nucleus, whilst it became puffed all around. I have seen a globule thus altered in its form, presenting three very distinct enlargements in the course of its long diameter, the two lateral of which exceeded the median one in extent. I should therefore be led to imagine that by the effect of an endosmosis these vesicles may occasionally absorb the water of the serum, and that this fluid, accumulating around the central nucleus, without, however, separating this corpuscle from its envelope, gives to the globule in general the form of a biconcave disc, as described by Dr. Young. This appearance, which is very common in the human blood, agrees extremely well with the description of Dr. Hodgkin and Mr. Lister, but we do not imagine that this is the normal condition, and we are persuaded that if these very scrupulous observers would but extend their inquiries to the blood of those animals in which the globules are most easily studied, they would return to and espouse the opinions of Hewson and of Prevost and Dumas in regard to the particular point at issue.

In the normal state, the membranous vesicle of the globules of the blood appears perfectly smooth among vertebrate animals; but among the invertebrata its surface is uneven and nodulated like that of a raspberry, as we have already said. Hewson, however, observed that when the blood of the vertebrata began to putrefy, the globules then presented an appearance analogous to what we have remarked in those of the crustacea and mollusca. In the mammalia the central nucleus is circular and depressed, and in all this class of animals it appears to be similar in size. In the oviparous vertebrata, it is on the contrary elliptical in figure, though, according to Messrs. Prevost and Dumas, it acquires this figure in consequence of a particular substance being fixed around it, itself being in reality circular, as among the mammalia.

It frequently happens that other smaller corpuscles than the globules of which we have treated hitherto are observed swimming in the serum. These are of a whitish colour and similar to the molecules that occur in almost all the fluids of the animal economy. The resemblance that exists between these corpuscles and the central nuclei of the proper globules of the blood might lead to the belief that they were nothing more than the central nuclei divested of their coloured envelope; but in several of the inferior tribes, as the river-crab and certain mollusca, in the blood of which they occur in very considerable numbers, the central nuclei of the globules are much larger, and it is impossible to confound the two together. These then are to be regarded, not as globules of the blood, properly so called, altered in any way, but as globules of albumen or fibrine. These substances, in fact, have always the appearance of being made up of circular corpuscles of extreme minuteness when by any means they are brought into the solid state; and we are led to believe that even when dissolved or suspended in water they still preserve this peculiar disposition, and only escape detection under the microscope by their dissemination and transparency.

To recapitulate, then, we find:—

1st. That the globules of the blood are membranous sacs inclosing a solid flattened nucleus in the form of a disc, in their interior.

2d. That their form and their dimensions vary among animals of different species, but that in the same animal they all bear the strongest resemblance to one another.

3d. That in the mammalia these corpuscles are circular and smaller than in any other class of animals.

4th. That in birds the globules of the blood are elliptical and larger than in the mammalia; their dimensions vary slightly in different genera, but this variety does not seem to extend further than to the admeasurements of their long diameters.

5th. That in vertebrate auimals with cold blood the globules are also elliptical, but that their dimensions are much greater and vary more extensively in different classes; reptiles, more especially the batrachia, are of all animals those in which the globules of the blood are the largest.

6th. That in the invertebrata the globules of the blood are more or less regularly circular in shape, and are also of very considerable dimensions.

It appears to be especially owing to the presence of the globules, the common physical properties of which we have thus far studied, that the blood owes its power of arousing and keeping up vital motion in the animal economy. We observe, in fact, that if an animal be bled till it falls into a state of syncope, and the further loss of blood is not prevented, all muscular motion quickly ceases, respiration is suspended, the heart pauses from its action, life is no longer manifested by any outward sign, and death soon becomes inevitable; but if, in this state, the blood of another animal of the same species be injected into the veins of the one to all appearance dead, we see with amazement this inanimate body return to life, gaining accessions of vitality with each new quantity of blood that is introduced, by-and-bye beginning to breathe freely, moving with ease, and finally walking as it was wont to do, and recovering completely. This operation, which is known under the name of *transfusion*, proves better than all that can be said the importance of the action of the globules of the blood upon the living tissues; for if, instead of blood, serum only, deprived of globules, be employed in the same manner, no other or further effect is produced than follows the injection of so much pure water, and death is no less an inevitable consequence of the hemorrhage.

A variety of other experiments upon transfusion, for which we are equally indebted to Messrs. Prevost and Dumas, show the influence which the form and volume of the globules of the blood exert upon its physiological properties. If the blood introduced into the veins of a living animal differs merely in the size, not in the form of its globules, a disturbance or derangement of the whole economy more or less remarkable supervenes. The pulse is increased in frequency, the temperature falls rapidly, the alvine evacuations become slimy and sanguinolent, and death in fine generally happens after the lapse of a few days. The effects produced by the injection of blood having circular globules into the veins of an animal the globules of whose blood are elliptical, (or *vice versa*,) are still more remarkable; death then usually takes place amidst nervous symptoms of extreme violence, and comparable in their rapidity to those that follow the introduction of the most energetic poisons.

We know by observation and experiment that it is the blood that supplies the living tissues with the materials which they assimilate to repair their losses resulting from the various processes of which they are the seat, as well as to add to their masses during the period of their growth; thus, when by mechanical means we lessen in a notable and permanent manner the quantity of this fluid received by any organ, we soon find it declining in size, and often shrinking almost to nothing; whilst on the other hand we see that the more blood any part receives, the more does it tend to increase in size. It has also been demonstrated that it is at the expense of the blood that the different glands prepare the fluids they are destined to secrete, for the ligature of the vessels which run to one of these organs is followed by the immediate cessation of its secreting function. From this it became an interesting question to determine whether or not the blood contains, ready formed, the various substances of which these tissues and these secreted fluids are composed, and if the organs it traverses do anything more than merely separate these from its mass, or whether the general nutrient fluid only supplies to the different parts of the economy the primary elements necessary to the formation of the substances of which we have spoken, which would then be originated by the tissues or glands in which they are encountered. To resolve this question, it became necessary to contrast the chemical composition of the tissues and fluids of the economy with that of the blood, and to ascertain whether the last-named fluid contained all the variety of substances which are met with elsewhere in the animal organization.

This very important part of organic chemistry is not yet sufficiently advanced to enable us completely to answer the question: all we know, however, goes to prove that the component parts of the tissues and secreted fluids exist in the blood ready formed, and are only separated from its general mass by the organs which at first sight seem to produce them. In the blood we discover—1st, water, an element which enters in large proportion into the composition of all the fluids, and even forms a considerable item in the constitution of all the tissues: 2d, fibrine, which forms the basis of the muscles: 3d, albumen, which is met with in variable but still considerable quantities in the brain, cellular substance, membranes generally, and in the greater number of the secreted fluids which are not excrementitious: 4th, a fatty phosporated matter, which enters into the composition of the nervous system: 5th, a peculiar colouring matter of a yellow hue, which, slightly modified, is perchance the same as the pigmentum nigrum of the choroid coat of the eye, and of melanosis: 6th, phosphate of lime and phosphate of magnesia, salts which form the inorganic basis of the bones: 7th, alkaline salts, which are met with in almost all the fluids of the body: 8th, cholesterine, a peculiar fatty matter existing very abundantly in the bile: 9th, urea, a substance characteristic of the urine: lastly, various other matters more or less accurately defined.

Under ordinary circumstances our means of analysis are inadequate to demonstrate the presence of urea in the blood; but if the action of the organs destined to separate this substance from its current in proportion as it is formed, be arrested, the amount contained goes on increasing continually, so that before long it becomes easy to distinguish it. Messrs. Prevost and Dumas have shown that, after the extirpation of the kidneys, the blood always contains urea in appreciable quantity.* This experiment, the results of which have been confirmed by Messrs. Vauquelin and Segalas, is of the highest importance, and shows that if we have hitherto failed to discover uric acid, caseum, and the other component elements of the principal fluids in the blood, we are not, therefore, to conclude that they do not exist there; analogy would even lead us to infer that they are actually present, and that if we were to interrupt the different glands in the performance of their functions, they would be discovered in appreciable quantity. Experiments conducted in this view would be extremely interesting. Another subject of inquiry, too, not less important, would be to discover the source of the gelatine which forms the basis of the cartilages, tendons, ligaments, &c. and which does not appear to exist in the blood.

The most complete analysis of the human blood we possess is that published lately by M. Lecanu, a chemist of Paris.† The careful examination of the blood of two strong and healthy men afforded the following results.

* Bibl. Univers. de Geneve, and An. de Chemie, 2de Serie, t. xxiii.

† Journal de Pharm. No. ix. and x., 1831.

	1st Analysis.	2d Analysis.
Water	780.145	785.590
Fibrine	2.100	3.565
Albumen	65.090	69.415
Colouring matter .	133.000	119.626
Fatty chrystallizable matter	2.430	4.300
Oily matter . . .	1.310	2.270
Extractive matters soluble in alcohol and in water . .	1.790	1.920
Albumen combined with soda . . .	1.265	2.010
Chloruret of potassium . . . ; Chloruret of sodium ; Alkaline sub-carbonates . . . . ; Alkaline phosphates ; Alkaline sulphates .	8.370	7.304
Sub-carbonate of lime . . . . ; Sub-carbonate of magnesia . . . ; Phosphate of lime . ; Phosphate of magnesia . . . . ; Phosphate of iron . ; Peroxide of iron .	2.100	1.414
Loss	2.400	2.586
Total . . .	1000.000	1000.000

Since the publication of the preceding analysis, M. Boudet has discovered a new substance in the serum of the blood, which he denominates *seroline*. This is a white slightly opalescent substance, fusible at 36 cent., (about 94° Fahr.), not forming an emulsion with water, soluble in alcohol, not saponifiable, and appearing to contain azote. This chemist has also shown that the oily matter mentioned by M. Lecanu is a mixture of cholesterine and an alkaline soap, similar to that which is met with in the bile; lastly, he has determined the identity of the fatty chrystallizable phosporated matter contained in the blood with that discovered by Vauquelin in the brain *(cerebrine)*.*

The study of the colouring matter of the blood has engrossed a large share of the attention of chemists; nevertheless its nature is still very imperfectly known. It is very commonly designated under the name of *hematozine* or *hematine*, and can be readily shown to have the greatest analogy to albumen, from which it is indeed always separated with great difficulty. This matter is soluble in pure water, insoluble in serum and in water impregnated with salt or sugar, coagulable by heat, capable of absorbing oxygen, carbonic acid, and various other gases which modify its colour. According to M. Lecanu the hematine of chemists is a combination of albumen and the pure colouring matter of the blood, which he proposes to designate *globuline*.* But his researches into this delicate subject do not seem to us altogether satisfactory, and we have reason to believe that his *globuline* is neither more nor less than some of the globules of the blood which have escaped the action of the subacetate of lead employed to precipitate the uncombined albumen. However this may be, the colouring matter of the blood after incineration leaves a large quantity of ashes, in which a considerable proportion of oxide of iron can be demonstrated, to the presence of which several chemists have ascribed the red colour of the blood; such an opinion, however, does not seem tenable at the present day.

The experiments of Berzelius have shown that the serum of the blood of the ox does not differ essentially from that of the blood of man.† But we are still without comparative analyses of the nutrient fluids of the different classes of animals. This desideratum has been partially supplied in regard to the vertebrata by Messrs. Prevost and Dumas, they having carefully determined the proportions of water, and of albumen contained in the serum, and those of the fibrine, and other solid parts which swim suspended in this fluid. From these experiments we learn that the composition of the serum varies in the same animal at different times, and that it differs still more widely in different animals, without its being possible to connect such changes with the physiological state of the individual. The case is otherwise, however, as concerns the globules; in the majority of cases there exists a remarkable relation between the quantity of these corpuscles and the degree of heat developed by the vital actions. Of this we may be easily convinced by inspecting the following table, in which Messrs. Prevost and Dumas have presented us with the comparative weights of the solid particles (globules and fibrine) contained in 1000 parts of blood, with the habitual temperature of different animals, taken in the rectum, the number of pulsations of the heart per minute, and the number of inspirations made in the same interval of time.

* Ann. de Chimie, 2de Serie, t. lii.

* Ann. de Chimie, 2de Serie, t. xlv.

† On animal fluids, in Med. Chirurg. Trans. vol. iii.

Names of the Animals.	Weight of the solid particles in 1000 parts of blood.	Composition of the serum.		Mean temperature.	Normal pulse per minute.	Normal number of inspirations per minute.
		Albumen.	Water.			
BIRDS.						
Pigeon	15.57	55	945	42° centigr.	136	34
Common fowl	15.71	75	925	41.5	140	30
Duck	15.01	99	901	42.5	110	21
Crow	14.66	66	934	..	..	..
Heron	13.26	68	932	41	200	22
MAMMALIA.						
Monkey	14.61	92	908	35.5	90	30
Man	12.92	100	900	39	72	18
Guinea-pig	12.80	100	900	38	140	36
Dog	12.38	74	926	37.4	90	28
Cat	12.04	96	904	38.5	100	24
Goat	10.20	93	907	39.2	84	24
Calf	9.12	99	901	..	..	..
Rabbit	9.38	109	891	38	120	36
Horse	9.20	99	901	36.8	56	16
Sheep	9.00	..	..	38	..	..
REPTILIA.						
Frog	6.90	50	950	9. in water.	..	20
Tortoise	15.06	96	904	7.5 that of the air.	..	3
FISHES.						
Trout	6.38	77	923	..	..	..
Loach	4.81	69	931	..	..	..
Eel	6.00	100	900	..	..	..

From these experiments it follows that of all animals birds are those whose blood is richest in globules and in fibrine, as they are those also whose temperature is highest and whose respiration is most active. The blood of the mammalia contains rather less, and there is a difference to be noted in this respect between the carnivorous or omnivorous tribes, and the herbivorous, the proportion of solid particles being larger in the two former than it is in the latter. We see, indeed, that in man, the dog, and the cat, they enter in the proportion of twelve or thirteen per 1000, whilst in the horse, sheep, calf, and rabbit, they form no more than from the seventh to the ninth per 1000 of the general weight of the blood. But the number of species hitherto examined is not so considerable as to enable us to say that the circumstance, now announced, is to be regarded in the light of a physiological law. Among the cold-blooded vertebrate animals the blood becomes much poorer in solid particles; the tortoise, indeed, seems, from the results in the table, to form an exception to this fact, but the circumstances under which the estimates were made in regard to it, and which it would be too long to enter upon here, explain the anomaly.*

The proportion of serum and of solid particles also presents considerable varieties in the blood of different individuals of the same species. From the investigations of M. Lecanu we observe that the proportion of water in the human blood varies from 853 to 778 in 1000, and that of the solid particles from 148 to 68.

The differences of sex have also a certain influence on the composition of the blood: M. Lecanu found in regard to

The blood of man (in 1000 parts.)

	Solid particles.	Water.
Maximum	148	805
Minimum	115	778
Mean	132	791

The blood of woman.

	Solid particles.	Water.
Maximum	129	853
Minimum	68	790
Mean	99	821

The quantity of albumen did not appear to differ in the blood of the two sexes.

The richness of the blood also varies according to the temperament of individuals as may be seen by the following table.

Men.

	Sanguine temperament.		Lymphatic temperament.	
	Solid particles	Water	Solid particles	Water
Maximum	148	801	117	805
Minimum	121	778	115	795
Mean	136	786	116	800
Women.				
Maximum	129	796	129	827
Minimum	121	790	92	790
Mean	126	793	117	802

* Ann. de Chimie, t. xxiii.

Lastly, the composition of the blood may also vary in the same individual according to a variety of circumstances. Prolonged abstinence from diluents, for example, tends to diminish the proportion of the watery particles of the blood, and, consequently, to render it richer in nutrient elements. Bloodletting produces the contrary effect; not only is the mass of circulating fluid by this means diminished, but it is also rendered poorer. Messrs. Prevost and Dumas having bled a cat largely, found its blood to consist of 791 of water, 87 of albumen, and 118 of globules. Two minutes afterwards they repeated the bleeding, and now only found 116 of globules, and 74 of albumen to 809 of water; after an interval of five minutes more the bleeding was repeated for the third time, and they found the blood to consist of 829 of water, 93 of solid particles, and 77 of albumen. M. Lecanu obtained similar results from the analysis of human blood taken from patients who had been bled several times in quick succession, or who were labouring under hæmorrhagic affections;* and the circumstance is readily explained, by supposing that the diminution of the mass of blood tends to accelerate absorption, the first effect of which must needs be to introduce a much larger proportion of water than of solid particles into the torrent of the circulation.

In its ordinary state the blood is always fluid, and consists, as we have seen, of a watery part, holding solid globules in suspension; but under certain circumstances its physical properties change completely: this happens whenever it is withdrawn from the vessels in which it is contained in the bodies of living animals, or in the event of an animal ceasing to exist. The blood left to itself changes within a few minutes into a mass of a gelatinous consistence, which gradually separates into two parts, one fluid, transparent, and of a yellowish colour, formed by the serum; another solid, quite opaque, and of a red colour, to which the name of *cruor*, *crassamentum*, or *clot* is given.

The mode in which this phenomenon happens, and the cause that occasions it, have engaged the attention of a great many physiologists. The experiments of Hunter and of many others show that the coagulation of the blood depends mainly on the cessation of the motion to which it is constantly subjected in the course of the circulation; for this condition alone suffices to make it coagulate even in the interior of the vascular system, and we are of opinion that the great physiologist just quoted erred in attributing vital properties to the blood. Rest, then, cessation from motion, is that which contributes most generally and most essentially to cause coagulation of the blood; other circumstances, however, such as its cooling, its being brought into contact with the air, &c. may also contribute to accelerate this phenomenon, which appears, from the experiments of Dr. John Davy, to be unaccompanied with any evolution of caloric.

* Journal de Pharmacie, 1831.

If a clot of blood be gently kneaded and pressed under a stream of water, it gradually becomes paler, and finally loses its red colour entirely, the colouring matter being washed away; what remains in the hand is a mass of whitish and very elastic filaments composed of fibrine. Or otherwise, if, instead of being left at rest, a quantity of freshly drawn blood be quickly stirred with a bundle of rods, a stringy mass of fibrine will be found adhering to these after a time, and the blood thus treated will not coagulate. This experiment shows that it is to the fibrine that the blood owes its property of coagulating.

The filaments of fibrine studied under the microscope are found to be formed by the aggregation of a multitude of white globules, bearing the greatest resemblance to the central nuclei of the proper globules of the blood. It was, therefore, natural to suppose that the formation of the coagulum depended on the spontaneous decomposition of these globules and the aggregation of their internal corpuscles. And such, indeed, is the theory which Messrs. Prevost and Dumas have given, and which has been adopted by the greater number of the physiologists of the present day. "The attraction," say they, "which keeps the red matter fixed around the white globules having ceased along with the motion of the fluid, these globules are left at liberty to obey the force which tends to make them combine and form a net-work, in the meshes or amid the plates of which the colouring matter is included along with a great quantity of particles which have escaped this spontaneous decomposition."*

It would appear, however, that this is not an exact explanation of the phenomenon, for Professor Müller, of Berlin, has succeeded in demonstrating that the coagulation of the blood is altogether independent of the globules, and that the fibrine which determines the phenomenon exists dissolved in the serum. By filtering with great care the blood of frogs, diluted with sugar-water, he separated the globules completely from the serum before coagulation took place: the fluid part of the blood alone passed the filter, the solid particles remained upon it; nevertheless, a coagulum formed within the fluid after the lapse of a few minutes; this, of course, was colourless instead of red, as it is when the red globules are entangled in the mass. This curious and interesting experiment does not succeed so well when human blood is employed, inasmuch as the globules, being much smaller than those of the blood of the frog, pass along with the serum through almost any filter that can be used. Still Professor Müller has succeeded in proving the existence of fibrine in the serum by means of the following procedure. If to a little blood contained in a watch-glass a few drops of a highly concentrated solution of subcarbonate of potash be added, the coagulation of the fluid is so much retarded, that the globules have time to sink to the bottom before it occurs. When coagulation takes place at

* Ann. de Chimie, t. 23, p. 51.

length, the clot extends as usual through the whole mass, but it is colourless on its upper part, and only red in the part into which the globules have subsided. Professor Müller believes that the fibrine exists in a state of solution in the serum, an opinion which to us appears hardly reconcilable with the known chemical properties of this substance; we are more inclined to suppose that, like the proper globules, it is merely suspended in the mass of the blood in a state of extreme subdivision, and possessed of transparency too perfect to admit of its being distinguished amidst the surrounding fluid.

There are circumstances under which the blood only coagulates with difficulty, or in which it even loses this property entirely. In cases of poisoning with hydrocyanic acid, for instance, the blood remains fluid and thick after death; the same thing also occurs after death from fever of a typhoid type, from lightning, &c.

Another phenomenon presented by the blood which is of very common occurrence, and depends on the manner in which it coagulates, consists in the formation of what is called an *inflammatory crust* or *buffy coat:* the coagulum, instead of being uniformly red, then appears covered with a greyish or yellowish viscid and very tough pellicle of various degrees of thickness. The phenomenon in question is principally observed in individuals labouring under acute inflammatory affections of the serous or synovial membranes, of the substance of the lungs, &c. but also occurs among persons in good health, although plethoric. The experiments of M. Ratier go to prove that various circumstances, altogether independent of the physiological state of the individual, may also exert great influence on the formation of the buffy coat: thus, *cæteris paribus*, it is more readily produced if the blood withdrawn be received in a deep and narrow vessel, and if the opening in the vein be large, and the jet be free. The cause of the buffy coat has been very satisfactorily explained; it depends on the more rapid subsidence than usual of the red globules, in consequence of which the more superficial parts of the coagulum contain none. From the experiments of Professor Müller it would also appear that this subsidence of the globules takes place more quickly if a thick solution of gum be added to the blood, so as to increase its density, whilst, when it is deprived of its fibrine by stirring with rods, these bodies remain for a very long time suspended. Now it follows, from the investigations of Sir C. Scudamore, that buffy blood contains a larger proportion of fibrine than usual, a state to which the more rapid deposition of the globules, and the formation of the inflammatory crust, which is its consequence, may be attributed.

Thus far we have only spoken of the blood in a general manner, and without respect to the part of the system in which this fluid is examined; it is, however, very far from being identical in every part, and there are wide differences between the physieal and physiological properties of arterial and of venous blood.

The blood which is tending to the several parts of the body is in the first place of a bright vermilion red colour *(arterial blood);* whilst that which has already passed through the different tissues, and is on its way back from them, is of a dusky or blackish red of various degrees of intensity *(venous blood).* Arterial blood also coagulates more quickly than venous blood, and, from the researches of Dr. John Davy, appears to have rather a less capacity for caloric,* and a somewhat inferior specific gravity (1,049 : 1,051); we are, however, led to think that in the normal state the contrary of the latter proposition will be found to obtain, for Messrs. Prevost and Dumas have shown that in this case arterial blood contains a larger proportion of globules than venous blood.†

When the physiological action of arterial and of venous blood is investigated, still more striking differences are discovered; the first maintains vital excitation in the economy, and the second is insufficient to support life. Physiologists have even gone so far as to regard the influence of the venous blood upon the brain as deleterious;‡ but more recent experiments show that though inadequate to keep up life, it is far from being a poison; on the contrary, it rather tends to prolong existence, for frogs whose vascular system is filled with this liquid die less speedily than those placed under similar circumstances, but which have lost almost the whole of their blood by hæmorrhage.§

The blood thus modified by the influence of the organs it permeates, is still susceptible of resuming its primary colour, and of acquiring at the same time its vivifying properties: it is enough to expose it to the contact of oxygen, to give it back all its peculiar qualities. We find, in fact, that if venous blood be agitated with atmospheric air, or better still with oxygen gas, it speedily assumes the vermilion tint that characterizes arterial blood, and if the air thus employed be afterwards analysed, a certain quantity of oxygen will be found to have disappeared, and its place to be occupied with a corresponding measure of carbonic acid. Now that which happens here under the influence of mere chemical affinity, also takes place in the animal economy, and it is even thus that venous blood in being exposed to the contact of atmospheric air in the respiratory apparatus, whatever its nature, changes into arterial blood and again becomes fit to minister to life. (See Respiration.) On the other hand, if vermilion-coloured blood be subjected to the action of carbonic acid, it speedily acquires a

* Philos. Trans. 1815.

† Ann. de Chimie, t. xxiii. p. 67.

‡ Bichat, sur la Vie et la Mort. See also the article Asphyxia.

§ M. Edwards, Influence des Agens Physiques sur la Vie, translated by Dr. Hodgkin.

deep or blackish hue, and then resembles venous blood in its appearance and properties.

It now became a question of the very highest importance in the theory of respiration to ascertain whether the oxygen acting upon the blood in the manner specified, produced the carbonic acid disengaged, by combining directly with carbon supplied by the colouring matter or some other element of the blood, or whether the oxygen was simply dissolved by the blood and in dissolving expelled the carbonic acid which existed in it ready formed.

Various experiments satisfy us that venous blood contains carbonic acid already formed. My brother, Dr. W. F. Edwards, has shown that those animals which possess the greatest powers of resisting asphyxia continue for a long time to disengage carbonic acid when kept in vessels filled with pure azote or hydrogen, circumstances under which it is impossible that the carbonic acid evolved can proceed from the direct combination of inspired oxygen with the carbon of the blood.

By placing venous blood under the receiver of an air-pump, several inquirers had indeed already found that bubbles of carbonic acid gas were disengaged from it, when the pressure of the atmosphere was withdrawn. This fact, first observed by Vogel,* has been verified by Messrs. Brande, Bauer,† and others. The quantity of carbonic acid disengaged in this way, however, is very small, and altogether inadequate to explain the phenomena accompanying respiration; but if, after having freed a quantity of blood as completely as possible from its carbonic acid by means of the air-pump, it be agitated with hydrogen or any other gas, this will be absorbed, and a fresh and corresponding disengagement of carbonic acid will be determined.‡ On the other hand there is an experiment of Girtanner, mentioned by Hassenfratz,§ which goes to prove that arterial blood contains a portion of free oxygen in its constitution; but this conclusion appears to require confirmation.

The bright vermilion or dusky red colour of the blood, however, does not depend solely on the nature of the gas it holds in solution, or with which its colouring matter is in combination. The recent experiments of Dr. Hoffmann shew that the presence of the saline matters it contains is necessary to the phenomena in question. Blood freed from these saline ingredients is black, and cannot be brought to the vermilion red tint as usual by the action of oxygen. The same physiologist also ascertained that the presence of an overdose of saline matter in blood charged with carbonic acid, equally prevented the ordinary action of oxygen in changing its colour.

The blood does not invariably exhibit the properties and the mode of composition which we have just ascribed to it in the normal state. There was a time when physicians ascribed the greater number of internal maladies to alterations of this fluid; the general erroneousness of this opinion, however, was at length detected, and at the present day pathologists have probably fallen into the opposite extreme, namely, that of neglecting the study of the changes which the blood does actually undergo, although these are sufficiently striking in many cases, and undoubtedly exert an immense influence upon the animal economy. A careful examination of their kinds and effects were undoubtedly fraught with results of equal importance in a medical as in a physiological point of view.

(H. Milne Edwards.)

* Schweigger's Journal, Bd. xi.
† Home, Croonian Lecture, Philos. Trans. 1818.
‡ Hoffmann, Lond. Med. Journ. May, 1828.
§ Ann. de Chimie, 1iere Serie, t. ix.

BLOOD, MORBID CONDITIONS OF THE.—The nature and properties of blood in its normal condition having been considered in the foregoing article, we proceed to notice those changes to which it is liable in a state of disease.

That a fluid which is destined to receive and convey materials for the formation, increase, and repair of every structure in the animal frame, which carries away whatever is useless, and is brought into perpetual contact with the external atmosphere, should itself be subject to morbid alterations, is a notion so natural, so entirely in accordance with what might *à priori* be expected, that, independently of all reasoning, and antecedently to all proof, it has existed in the common belief of every age and of every nation.

To preserve a healthy state of the blood has accordingly ever been considered an object of primary importance. The greatest pains have been taken to maintain its purity, as well in the individual as the species; not only in man, but in all those animals which he has domesticated for his use; and there is no belief more generally received than that which attributes the origin of many of the cutaneous eruptions, and of most of the cachectic diseases, to the degeneracy and poverty of this vital stream.

When from this general and popular notion we advance to the more especial assumption that the origin of all diseases is to be found in the blood and other fluids; when we classify these into hot and cold, moist and dry, or into blood, bile, black bile and phlegm, and attribute morbid changes and even natural dispositions to the prevalence of one or other of these supposed humours, we quit the belief of the people to follow theories far less tenable, invented at a period when authoritative assertions had the weight of proof, and when the dogmata of a philosopher were preferred to facts plainly recorded in the book of nature.

It would be out of place here to enter into a discussion of the merits of the humoral pathology as compared with the various doctrines which have supplanted it, and to which it is not unlikely that in an improved form it may again succeed.

Under the triple relation of vital phenomena, intimate structure, and chemical composition, as

Andral* justly remarks, we can draw no definite line of demarcation between the blood and the solids. Physiologically speaking, we cannot conceive that of these two facts which form a single whole, the one can be modified without affecting the other. Since the blood nourishes the solids, they must necessarily be influenced by its state; and since the solids furnish materials from which the blood is formed, and abstract materials by which it is decomposed, any alteration in the nature or quantity of these must necessarily have its influence on this fluid. Suffice it then to observe that the further we extend our knowledge of pathology, the less shall we feel inclined to admit the exclusive claims either of fluidism or solidism, and the more shall we strengthen our belief that the animal structure is composed of parts, every one of which may not only partake of disease, but, under certain circumstances, become its cause.

Quitting, therefore, all unprofitable speculations on this subject, we proceed at once to a detail of facts, and to such observations in elucidation of them as occasion may suggest.

Blood may be excessive in quantity, thus constituting a state of plethora in which the circulating system is supplied more abundantly than is needed for the due performance of the functions of nutrition and secretion. A tendency to accumulation in the capillaries and in the different internal organs is induced, and congestion with its consequences, or actual rupture of the bloodvessels, is the result. Drowsiness, vertigo, headache, epilepsy, apoplexy, mark this state as existing in the head; dyspnœa, and a livid or purple hue of the skin, as affecting the lungs; palpitation and irregular action with syncope mark the ineffectual struggle of the heart to propel its contents. Hæmorrhages from the mucous membranes of the nose, the lungs, or the intestines, are often the consequence of congestion in the vessels which ramify on their surface; while indigestion, torpor, and biliary redundancy, are connected with a plethoric condition of the abdominal viscera. Although the existence of such a state, as deducible from the symptoms just enumerated, as well as from the effect which depletion has in removing them, admits of no doubt, it has, nevertheless, not been made the subject of direct proof. The proportion which the circulating blood, even in a healthy animal, bears to its total weight has not been, and, perhaps, cannot be ascertained with precision. Haller collects together many authorities at variance with each other on this point, and at length comes to the conclusion, "Neque dissimulandum est, obiter hæc et vage definiri. Infinita enim procul dubio in ratione sanguinis ad reliquam corporis molem varietas est." †

Fat men and animals have less blood than lean, old than young; and yet plethora is oftener found in the former than the latter, obviously on account of the mechanical impediment which the encumbered tissue or the rigid fibre offers to the circulation.

The state of anæmia, or a deficiency in the quantity of circulating blood, whether induced by natural or artificial causes, is no less detrimental to health than its excess. Its symptoms are general pallor, weak circulation, languor, syncope with palpitations, oppressed respiration, flatulency, general œdema, and, in extreme cases, effusion into all the serous cavities.

Neither plethora nor anæmia necessarily imply, though they are generally complicated with some morbid change in the blood itself. We therefore pass them over with this slight notice, referring for further information to the excellent observations of Andral, in his work on Pathological Anatomy.

The circulating blood consists essentially of a homogeneous fluid and red particles, and the former, when removed from the body or from the circulation, separates into a fluid and a solid portion. The solid, when washed and freed from the serum and red particles which are mechanically entangled in its substance, constitutes the proximate animal principle called fibrine. The fluid contains water, albumen, oil, animal extractive, and salts, alkaline, earthy, and metallic.

With the exception of the oil and fatty matter, which, in a healthy state of the blood, do not amount to four parts in a thousand, its constituents are all heavier than water, and something is to be learned by ascertaining its specific gravity. In the information thus gained, however, we are limited to the alternative, either that some one or more of these constituents is in a state of excess or of deficiency, the proportion of water remaining normal, or that the water itself is either superabundant or deficient.

The specific gravity of healthy blood has been variously stated by different authors. Haller makes it on the average 1,052; Blumenbach, 1,054; Berzelius, from 1,0527 to 1.057; Denis, 1,059; but none of these authors note the temperature at which it was taken, although, from their manner of ascertaining it, there must have been considerable variety in this respect. By experiments which I have often repeated with an accurate specific gravity bottle holding 1,000 grains of distilled water, I find that with that fluid four degrees of Fahrenheit's thermometer corresponds with a difference of ·001 of specific weight, water being 1,000. Consequently, if one author states the specific gravity of blood at its circulating temperature 98° Fahrenheit, while another states it at 60° Fahrenheit, the usual standard, the former will make it ·0095 lighter than the latter.

The heaviest blood of which I find a record among my own observations was that of a man suffering under diabetes mellitus. At a temperature of 87° Fahrenheit it was of specific gravity 1·0615, while that of the serum was under the average standard of health, namely, 1·027 at 60° Fahrenheit, and of the medium proportion to the crassamentum, being, after twelve

* Précis d'Anatomie Pathologique, p. 526.

† Elementa Physiologiæ, tom. ii. p. 5.

hours' rest, as 1000 to 1323. The specific gravity of the crassamentum was 1·088.

The lightest blood which I have met with was of specific gravity 1·031, at 90° Fahrenheit. It was taken from the arm of a female, aged 22, who was bled on account of headach, and had a full pulse of 117.

The red particles being the heaviest of all the constituents of the blood, their relative quantity must greatly affect its specific gravity; and as Messrs. Prevost and Dumas have shewn that they bear a general proportion to the degree of animal heat, we might reasonably suppose that, *cæteris paribus*, the heaviest blood would be found in those diseases which are marked by high action and increased temperament. In a fluid so complicated, however, in which every constituent is liable to such variety in quantity, it is difficult to estimate the precise influence of each. I am not aware that any experiments have been made on this subject.

Blood diminishes in specific gravity in proportion to its frequent abstraction, for the red particles and the fibrine are reproduced with more difficulty than the serum or the salts. The serum also becomes lighter from a gradual diminution of its solid contents. A recent paper by Mr. Andrews, in the fifteenth volume of the Medical Gazette, p. 592, proves these facts very satisfactorily by experiments made on calves. They have, however, been long known.

The specific gravity of morbid blood, says Thackrah, differs little from that of healthy blood; but this observation is only true of an average deduced from numerous specimens of blood examined under different forms of disease. It would be equally true, perhaps, according to the same mode of obtaining a result, were we to affirm that the temperature of the body or the state of the pulse differed little in health and disease, since there might be as many instances of deficiency as of excess in heat or action. The assertion is not applicable to particular cases, and is, therefore, without value. Blood may be morbid from an undue proportion of any of its constituents, and it will be heavier or lighter than healthy blood according to the preponderance of the heavier or lighter principles. Where the specific weight is increased, it is generally owing to a deficiency in the proportion of water, as in the blood of cholera and diabetes; sometimes to an increase of fibrine and red particles, as in plethora, gout, and rheumatism.

The following table, containing the specific gravities of blood under several forms of disease, is compiled from a few cases of my own which were recorded for another purpose. Though short, it will be sufficient to shew that considerable variety occurs, and may collaterally suggest that in determining the propriety of depletion, it may in some cases become important thus to ascertain the proportion of solid matter existing in the circulation. A specific gravity bottle, holding 1000 grains of distilled water, was employed in all the experiments, so that the proportion of serum to clot was not influenced by variation in the shape or material of the receiver.

Sex.	Age.	Disease.	Blood. Sp. Gr.	Blood. Temp.	Serum. Sp. Gr.	Serum. Temp.	Nature of the clot.	Proportion of serum to clot.
Male	64	Dyspnœa and cough	1·048	78 Ft.	1·030	50 Ft.	Gelatinous, buffed, not firm	As 1000 to 1381
Ditto	18	Dyspepsia, with palpitation	1·052	78 „	1·031	55 „	....	„ 1000 „ 1366
Female	22	Pain in left side from a fall	1·043	86 „	1·026	55 „	Weak, loose, not buffed	„ 1000 „ 1040
Ditto	34	Hæmoptysis	1·045	55 „	1·027	55 „	Cupped, and thinly buffed	„ 1000 „ 745
Ditto	22	Vertigo........................	1·031	90 „	1·025	55 „	....	„ 1000 „ 380
Ditto	40	....	1·051	87 „	1·032	55 „	Not buffed	„ 1000 „ 2906
Male	60	Purpura	1·049	87 „	1·027	65 „	Gelatinous buff, not cupped; serum deep yellow........	„ 1000 „ 1495
Ditto	22	Vertigo	1·049	87 „	1·027	70 „	Dark, grumous, and scarcely coherent	„ 1000 „ 1156
Pregnant fem.	24	Vertigo	1·049	60 „	1·028	60 „	Florid red, not firm, nor buffed	„ 1000 „ 945
Male	40	Phthisis	1·044	87 „	1·028	60 „	Firm, with bluish white buff	„ 1000 „ 960
Ditto	38	Diabetes Mellitus	1·061	87 „	1·027	60 „	Buff doubtful, being drawn in a phial	„ 1000 „ 1323
Ditto	35	Diabetes Mellitus	1·048	90 „	1·024	60 „	Loose, almost diffluent, tough white buff, with milky serum	„ 1000 „ 1292
Same person	..	.. subsequent bleeding	1·049	60 „	1·025	60 „	Ditto, serum equally milky	„ 1000 „ 1479
Female	24	Headach	1·050	60 „	1·029	60 „	Firm, not buffed.	
Male	54	Diseased kidney, with coagulable urine	1·041	83 „	1·021	68 „	Not buffed.	

The specific gravity of morbid serum has been much oftener ascertained than that of morbid blood, and it leads to more precise information. The normal proportion of salts does not raise the specific gravity of serum above that of distilled water more than five parts in 1000.* The excess beyond this increase is owing to the presence of albumen. The quantity of other animal matter is too small to be worth taking into the account. Hence the specific gravity of serum indicates with tolerable accuracy the quantity of albumen it contains.

In some states of disease, where albumen is rapidly carried out of the system, as in diseased kidneys, in dropsies, and in profuse hæmorrhages, the specific gravity of serum has been observed as low as 1·013,† whilst in other states, where water and even salts are removed, as in cholera, it is found as high as 1·041.‡

Neither the specific gravity of fibrine nor of red particles has been hitherto stated by authors. The former, by immersion in solution of salt, I find to be 1·079 at 60° Fahrenheit. Some of the latter will fall to the bottom of a solution of specific gravity 1·129, and when agitated with a solution of even specific gravity 1·207, which is the point of saturation, will not rise to the top; but the experiment is not conclusive, for the red particles certainly undergo some change by the addition of salt in solution.

The temperature of the blood is materially influenced by disease. In fevers it is generally though not always above the healthy standard. In the cold stage of an intermittent the temperature of the skin has, according to Dr. Wilson Philip, been observed as low as 74° Fahrenheit, while in its hot stage it has increased to 105°. A corresponding diminution or increase in the temperature of the blood in all probability occurred in these cases. Haller cites authorities to prove that in pleurisy and yellow fever the temperature of the blood has been known to rise to 102° and 104°, in intermittent fever to 106° and 108°, and in continued fever to 109°. Morgagni devotes several pages to the history of a woman, as related in the journal of a cotemporary, Media Via, whose blood flowed in an icy cold state from the arm. The serum of this blood was in small proportion and of a yellow colour; the crassamentum black and viscid. This person seems to have undergone repeated venesection. Thackrah witnessed a similar phenomenon.

Whatever theory may be adopted respecting the generation of animal heat, it is a fact which is generally admitted, that it is effected through the medium of the blood, that it is, *cæteris paribus*, increased in proportion to the velocity, freedom, and force of the circulation, and that it is mainly dependent for its development upon the presence of the red particles. Wherever these are deficient, either from natural disease or artificial depletion, animal heat is deficient likewise. Chlorotic females and those who are subject to habitual losses of blood usually suffer from coldness of the extremities. The phenomenon of fainting is always accompanied by diminished temperature; and whenever we cut off the supply of blood from a limb, it loses its natural warmth as an immediate consequence. Plethoric subjects, on the contrary, provided their circulation be unimpeded at its capillary extremities, or in the process of the pulmonary ventilation, are liable to preternatural heat of the surface and profuse perspiration. As an actual diminution or increase in the quantity of the red particles produces a corresponding increase or diminution of animal heat, notwithstanding the natural change of venous to arterial blood, so likewise any cause which impedes that change, although the red particles be not deficient in quantity, will produce a like effect. Thus, in diseases of the heart, in pulmonary obstructions, especially of a spasmodic character, in the cold fit of ague, and in Asiatic cholera, there is a diminution of the natural warmth, although there is no reason to suppose that the red particles are actually less abundant than in health.

Fibrine may undergo alterations in quality during disease. In the healthy state it is composed of definite quantities of oxygen, hydrogen, azote, and carbon; and it is quite possible that some variety in the proportion of these constituents may give rise in disease to morbid states of that principle. Huxham observes that in malignant petechial fevers the crasis is so broken as to deposit a sooty powder at the bottom of the vessel, the upper part being either a livid gore, or a dark green, and exceedingly soft jelly. De Haen saw the blood in a dissolved state, and in the plague the blood is said not to coagulate.

In some persons there exists a state of constitution, bordering no doubt upon passive hæmorrhagic disease, in which the blood is observed either to coagulate very imperfectly or not at all. Alarming hæmorrhages from the slightest wounds are the consequence of such a diathesis, and the most powerful styptics will not always succeed in preventing their fatal termination. Dr. Wardrop, in a small work just published, has collected together several interesting cases of this kind, and from some of these it is demonstrated that such a condition may exist in many members of the same family, and even sometimes become hereditary.

In the dead body blood is sometimes found in a liquid state, resembling water, holding in suspension a red, brown, or black colouring matter. In this case, according to M. Andral, it has been demonstrated chemically that it still contains fibrine, but altered in its character, so as to be no longer coagulable. This dissolved state of blood observable after death is probably the same as that which exists in sea-scurvy, in putrid and typhous fevers, and in the latter stages of fatally terminating diseases characterized by defective nervous energy. It is matter of more common observation, however, that fibrine alters materially in its relative quantity. We often find that the clot is large in proportion to the serum, which may indeed arise from its being loose and defective in con-

* Med.-Chir. Trans. vol. xvi. part i. p. 57.
† Bright's Reports, vol. i. p. 85.
‡ O'Shaughnessy's Report on Cholera, p. 29.

tractility, so as to contain a large portion of fluid, or from its holding entangled among its meshes an unusual number of red particles; but it will often also arise from there being a more than ordinary quantity of fibrine present, in which case it will be firm and contractile as well as voluminous. Blood thus circumstanced is said to be rich and thick, and is generally met with in those whose complaints are connected with a plethoric habit.

A deficiency in the proportion of fibrine is likewise not unfrequent among those who suffer from complaints of debility, or who have lost much blood by natural or artificial depletions. In this case the clot is small, and has but little contractile power.

It is, I conceive, a possible case, that the fibrine may separate imperfectly or not at all, in consequence of an augmented proportion of salts, which out of the body we know to be capable of suspending coagulation altogether. The continued use of alkaline remedies will probably tend to produce a like effect.

Fibrine coagulates the more speedily in porportion as the circulating and nervous systems become more feeble. The experiment has been repeatedly made with animals that are killed by bleeding, and the last portions of blood invariably coagulate soonest. "The principle of the blood's speedy concretion in debility is important in a curative point of view. The first natural check to hæmorrhage is known to be the formation of a clot on the mouth of the vessel. If the longer the hæmorrhage the less had been the disposition to form such a clot, the wounded on the field of battle, and those injured by common accidents, who cannot promptly procure the aid of a surgeon, must inevitably have perished."*

One of the most remarkable and frequent deviations from the normal condition of blood removed from the body by venesection, is the occurrence of the buffy coat, which is a layer of fibrine occupying the surface of the crassamentum. The blood, whilst circulating within its vessels, consists, as I have already remarked, of a fluid which I have elsewhere ventured to call *liquor sanguinis*, and of insoluble red particles. These being in constant motion are uniformly diffused throughout this *liquor;* but their specific gravity being much greater than that of the medium in which they are suspended, they have a tendency to gravitate whenever that motion ceases. In healthy blood the fibrine coagulates so quickly that the red particles have not time to subside, so as to leave any portion of the *liquor* entirely free from them. By protracted fluidity this result is effected; the red particles do then gravitate to a greater or less depth before the *liquor* separates into two parts. A general coagulation of the fibrine at length occurs, and a clot is formed. That part of it through which the red particles had fallen becomes a layer of fibrine free from colour, and merely having some serum mechanically retained in its meshes, while the subjacent portion is of intense depth of shade, especially at the bottom, and of less than ordinary cohesion. In extreme cases, such an abundance of red particles reaches the bottom of the vessel that they are there found in a state of fluidity. The buffed layer sometimes assumes a cupped form, which is clearly owing to unequal contraction. The upper surface being freer from intervening red particles, contracts more powerfully than the under, and a concavity of the surface is the necessary consequence. Where, however, the contraction is weaker, the weight of the subjacent red clot, which is one and the same mass with the upper colourless portion, weighs this down, and keeps it in a horizontal position.

The crassamentum of arterial as well as of venous blood has frequently been observed to exhibit a buffy coat. It is rarely seen in blood extracted by cupping-glasses, and never in that pressed from leeches. It occurs in the lower animals, and is observed as frequently in the horse as in the human subject; indeed, from the quantity of blood usually drawn from that animal, it is still more strikingly apparent, being occasionally several inches thick. It has been denied that the cupped appearance is ever met with in the blood of the horse; but if this be received into a sufficiently small vessel, it will be in some instances as complete as in blood taken from the human subject. There are varieties in the appearance of the buffed coat which it is worth while to notice. It is generally of a firm uniform consistence, and of a light yellow or buff colour, whence its name. Sometimes, however, it is of a more spongy texture, and of a white or bluish, and more transparent hue. Two layers of buff are occasionally seen; the upper soft or friable, the inferior more compact. "There is a difference," says Sir Gilbert Blane, "in the appearance of the blood when sizy, perhaps not sufficiently insisted on by practical writers; for though there should even be a very thick buff, yet if the surface is flat, and the crassamentum tender, no great inflammation is indicated in comparison of that state of the blood wherein the surface is cupped, the crassamentum contracted so as to form the appearance of a large proportion of serum, and where it feels firm and tenacious, though perhaps but thinly covered with buff."*

From the examination of several specimens of buffed blood, I was at one time led to believe that its serum was always deficient in its due proportion of albumen; but this I have since found not to be the case, having met with blood thickly buffed, the serum of which at 60° Fahr. had a specific gravity of only 1·024, and with another specimen where the layer of fibrine was equally thick, of which, at the same temperature, the serum had a specific gravity of 1·040. Dr. John Davy examined the specific gravity of buffed blood in eleven cases. In five of them in which the buffy coat was slight, the specific gravities were 1·047, 1·051, 1·054, 1·055, 1·054; in five others in which the buffy coat was moderately thick, the

* Thackrah, p. 188.

* Blane on the Diseases of Seamen, note to page 314.

specific gravities were 1·044, 1·038, 1·052, 1·056; and in one instance in which it was thick, the specific gravity was 1·057. Taking the mean gravity of healthy blood at 1·044, which I believe will be found correct, it would thus appear that the buffy coat is more frequent in blood above than below the mean weight; but it is also clear that it may exist in either state, and the number of experiments is not sufficient to lead to any conclusive result.

De Haen, Hewson, and others have met with cavities in the crassamentum of buffed blood containing clear fluid (liquor sanguinis), which, on being evacuated several hours afterwards, separated into fibrine and serum. This fact is analogous to that of fluid blood having been found by Hewson in the heart of a dog thirteen hours after death, which blood, on being removed, coagulated soon after exposure to the air. A similar coagulation will occasionally take place in fluid blood taken from the human heart several hours after the extinction of life.

The remote cause on which the occurrence of the buffy coat depends appears to be an increased action in the circulating system, dependent on increased nervous energy, and this is capable of being very speedily excited. Thus it has happened* that blood from the same orifice drawn into four cups has exhibited this appearance in the second or the third cup, and not in the first or last, the difference being plainly owing to a faintness felt at the commencement and termination of the venesection. Thus also the blood of healthy horses drawn immediately after a smart gallop while the circulation is powerful and rapid, will exhibit a buffy coat, while that previously abstracted will of course shew no such appearance. Scudamore, it is true, arrived at an opposite result in the case of a young man whom he bled, and after causing him to run two miles, bled again. Neither before nor after the race was the blood buffed, but it is obvious that such severe exercise after depletion would exhaust rather than augment the powers of the nervous and circulating systems. Accordingly he found the proportion of fibrine diminished in the blood last drawn, while the specific gravity of the serum was increased from 1·030 to 1·035, thus shewing how large a quantity of moisture must have been carried off by perspiration.

The buffy coat, as might be anticipated from its cause, is usually found in connexion with those diseases and even conditions of health in which vascular action is preternaturally increased—in the active stages of peripneumony, in pleurisy, in inflammatory fever, scarlatina and the eruptive diseases generally, and very uniformly in acute rheumatism. It is also occasionally but not always met with in the blood of pregnant women, in persons of sanguine temperament and full habit, and those who resort to frequent bloodletting; in chronic rheumatism, gout, enlargement of the heart, and other affections where no inflammation exists. On the other hand, it may be absent even in the most intense inflammation; for the circulation may be so overcharged either actually or relatively, or the nervous power so oppressed, that the requisite degree of propulsive force is not exerted by the heart and arteries, nor the vital energy on which slow coagulation depends imparted to the blood. In such instances the buffed coat generally appears on a second or third repetition of venesection.

Louis found the blood covered by a firm thick buff at each bleeding in nineteen cases of fatal peripneumony out of twenty-four. In two-fifths it was cupped. In fifty-one out of fifty-seven cases of recovery the blood was buffed, and in twenty-three cupped. In nine tenths of rheumatic patients the buff was firm and thick.

The form of the receiving vessel, the degree of motion to which it is subjected, and the size of the orifice in the vein, materially influence the phenomenon. M. Belhomme, the experimenter under M. Recamier, has made about one hundred and fifty experiments on blood drawn in health and disease. He has come to the conclusion that a medium orifice one line in the vein, a strong, rapid, and continuous jet in the form of an arch, and a narrow vessel for the reception of the blood, are the external circumstances most favourable for producing the buffy coat.*

Fibrine is more abundant in buffed than in healthy blood. Dr. Davy, from his observations, infers that there is no constant relation between the appearance of this covering and the proportion of fibrine in the crassamentum, yet his own tabular report contradicts him. "From all the examinations we have made," says Thackrah, who has made many experiments to determine this point, "I infer without hesitation that buffed blood contains a considerably greater proportion of fibrine than healthy blood." This is a fact of much interest and importance, for as very slight aud sudden causes may give rise to the formation of a buffed coat, we are thence led to infer that the quantity of insoluble matter which separates from liquor sanguinis by coagulation is variable, and that there is so far reason to believe that fibrine and albumen are principles convertible into each other.

In connection with the appearances dependent upon the slow coagulation of fibrine, I may here notice the occurrence of what have been termed polypi, or more recently and correctly, false polypi in the heart and larger vessels. These are so common, that, as Haller observes, scarcely a body is met with in which they do not exist. They are found in both auricles and both ventricles and in the larger arteries and veins, as well of the trunk as of the extremities. They consist essentially of fibrine, and partake of all the varieties that are observable in the fibrinous coat of buffed blood. Haller affirms, as usual, supporting his opinion by numerous authorities, that these have been known to exist even during life, not only in

* See Hewson on the blood, vol. i. p. 82 et seq.

* See also Med.-Chir. Trans. vol. xvi. p. 296, note.

man but in the larger warm-blooded animals, and adverts to a disease, *la gourme*, common among horses, which arises from a coagulation of the blood in the large arteries and veins and in the heart. Thackrah is of the same opinion, and Dr. George Burrows, who has made the changes which take place in the blood when its circulation is stopped in the living body, the subject of the Croonian Lectures of the present year, states that "there can be but little doubt that in some cases the blood coagulates in the heart during life. The firmness of the clots found in its cavities after death—their close adhesion to the lining of the heart—the presence of various fluids in the centre of these clots—the occasional organization of the coagulated masses, and their partial conversion into structures which are similar to new growths in other parts of the body—are facts which lead us to the conviction that the blood often coagulates in the heart long prior to death."

That such coagulation may take place during life I am willing to admit, but I am by no means led to the conviction that such an event *often* occurs. To the formation of a firm coagulum I am persuaded that rest is absolutely necessary, and I must consider it as a very rare occurrence that the contents of the cavities of the heart should be at rest during life. The usual appearance of false polypi is such as would take place in blood that coagulated very slowly, whether in or out of the body. Mr. Thackrah has proved that the blood when at rest coagulates much more slowly in living vessels, among which his experiments include vessels recently removed from living animals,* than in those that are dead; and I conceive that the human body, long after the heart has ceased to beat, and when it is, in the common acceptation of the term, dead, is still endowed, like the vessel just separated from the living animal, with a sufficient share of vitality to keep the blood which is in the heart and larger vessels in a fluid state, and thus to permit its coagulation to take place at length far more slowly than under ordinary circumstances. The following fact will perhaps be considered to have some interest as bearing on this point. I was engaged in the post-mortem examination of a gentleman who had died apoplectic from softening of the brain, which had given rise to effusion into the ventricles and under the pia mater; and being desirous of examining the fluid thus effused, I collected it with a clean sponge, by successively dipping this into the ventricles, and squeezing the fluid into a small cup. With a view to increase the quantity, I used the sponge also in soaking up some of the same fluid which had been caught in the calvaria, but was somewhat tinged with red particles. The cup was set apart till the conclusion of the examination, which lasted an hour and a half, when, on proceeding to transfer its contents to a phial, I was not a little surprised to find that a bulky clot of a rose colour and perfectly distinct was formed in the fluid. The examination in question took place twenty-two hours after death. As long as galvanism will stimulate the muscular structures to convulsive movement, so long at least may we conceive such a portion of vitality to remain as will influence the state of the blood. The fluid thus circumstanced exhibits the same phenomena, though in a more marked degree, which we observe in buffed blood out of the body. The red particles subside and leave the liquor sanguinis free from colour. In due time this separates into fibrine and serum: the coagulation takes place uniformly and universally, and in the larger cavities and vessels a colourless clot is left, which is moulded into their exact shape. The serum drains off, and washes away the red particles into the more depending and distant vessels. Thus it is that where we find polypi in the heart, we often find the descending aorta and the vena cava inferior filled with fluid, in which there is no fibrine at all. The firmness of a polypus affords no proof that it existed during life, or rather before respiration and circulation had ceased; for what can be firmer than the buffed coat which we often see formed out of the body? Its close adhesion to the lining of the heart is generally in appearance only, and is occasioned by the exactness with which it has adapted itself to every cavity and sinus, and enveloped every column, and the force with which the heart itself has contracted upon it. The presence of fluid in the centre, however difficult to account for, is also occasionally met with in the crassamentum of blood abstracted from the arm;* and even purulent matter, said to be found in false polypi, is occasionally formed out of the body. "In some rare cases I have seen the fibrine," says Andral, "assume a different aspect. The blood had no clot, and instead of it we observed at the bottom of the basin a kind of homogeneous purulent matter of a deep brown or dirty grey colour, and rather resembling sanies than blood."

With regard to the existence of organization, it seems to me that sufficient distinction has not usually been made between those cases where the lining membrane of the cavities of the heart or vessels has been ruptured, and which in so far are of the character of aneurism, and those where that membrane has remained entire. I am willing to admit that where there is a lesion of surface, adventitious growths will readily spring from it; but their substance is furnished from the structure beneath, and not from the circulating fluid. As an instance, I may mention the case of a youth who, being in perfect health, received a sudden shock from the unexpected discharge of a pistol close to his ear. He immediately felt conscious that something had given way in his heart, and from that hour suffered from palpitation, occasional syncope, with the usual symptoms of obstructed circulation, and died of general dropsy at the end of eighteen months. On examination after death the mitral valve was found to be obstructed by a fringe of excrescences, originating no doubt from a rupture of

* Thackrah on the Blood, p. 85, expt. lii. & liii.

* See Hewson, p. 69 and 70.

the valve itself, which had taken place at the time of the sudden surprise. This kind of growth, as well as that which is formed on the inflamed surface in endocarditis, has a sufficiently evident origin. We can also readily account for organized structures arising from aneurisms of the heart or arteries, accidental wounds of the latter vessels, ruptures of their inner membrane by ligatures, or its destruction by inflammation. I can, however, imagine nothing more unlikely than that an insulated mass of fibrine owing its origin to the mere coagulation of the blood from rest, and therefore only by gravitation brought in contact with the sides of the vessel which may contain it, should assume an organized structure, and that, too, at a time when the powers of life are so much enfeebled that the heart itself ceases to perform its office. I have looked carefully for unequivocal signs of vitality in these false polypi, and I confess that I have never been able to satisfy myself of its existence.

The albumen has not been demonstrated to be subject to alteration in quality. Its distinguishing characteristic of coagulating by heat is preserved even after it has become in the highest degree offensive from putridity.* It may be excessive or defective in proportion, and M. Gendrin has shewn that under inflammation of the system, the serum contains twice as much albumen as in the healthy state. Andral affirms that even by the touch, we may, from its viscidity, recognise serum that is surcharged with albumen. Its specific gravity, however, of which the French writers seem to take little note, would be a far better guide, and would indicate alike the defect as the excess of this principle. M. Gendrin has occasionally observed a mucous layer either at the bottom of the serum, or suspended in it. This is, in all probability, a minute portion of fibrine separating in the form of a flocculent cloud; for serum is capable of holding a certain portion of fibrine in solution, which after a time separates from it. This was first proved by Dr. Dowler,† who, on pressing the buffed coat of blood, extracted from it a liquid serum, which, on being allowed to rest for some time, exhibited signs of coagulation. With regard to the relative proportions of the serum and the clot, I have proved elsewhere‡ that this depends much on the vessel into which the blood is received. I shall show experimentally, however, in treating of diseased kidney, that an opposite state to that above alluded to as occurring, according to M. Gendrin, in inflammation, takes place under certain forms of disease where albumen is passing out of the system by the urinary passages. Thackrah lays it down as a law, to which he has found no exception, that in all cases in which the proportion of fibrine is considerably above the normal standard, the solid matter in the serum is below it. He cites ten examples in proof of his assertion, and puts it as a question whether we may not hence suppose that the albumen is taken from the serum for the formation of fibrine? The fact itself, however, requires confirmation, being in direct opposition to M. Gendrin's statement, that the proportion of albumen is greatly increased in an inflammatory condition of the system, which is precisely that condition when in general we find buffed blood, and therefore, according to Thackrah, an increase in the proportion of fibrine.

The hæmatosine is the least destructible of all the elements of the blood, retaining its qualities in that fluid after having been kept for several years. It is liable to much variety in its proportion, and in all those diseases and states of system in which hemorrhages occur, it gradually diminishes, at least to a certain point, in proportion to their extent and duration. In what part of the system the red particles are elaborated remains for the present a mystery. That they are reproduced slowly is manifested by the fact that those who have suffered large losses of blood, remain exsanguine for many months or even years afterwards. The same conclusion may also be deduced from the circumstance that women have a smaller proportion of red particles than men, the difference having been shewn by M. Lecanu to be attributable to the monthly loss which they habitually experience. Besides change of colour, to which the red particles are liable during disease, and which, among other causes, may arise from an altered proportion in the saline matters contained in the blood, they also appear to undergo structural alterations. In fevers, in malignant diseases, in sea-scurvy, in cases of poisoning, and of asphyxia from lightning, a permanently liquid state of the blood occurs, wherein the colouring matter of the globules appears to have lost its character of insolubility in the serum, and to be capable of percolating those tissues which are otherwise destined to contain it. Passive hemorrhages, petechiæ, and ecchymoses, are the results during life; and, after death, a stained condition of the lining membrane of the heart, the arteries, and veins, which has often been mistaken for vascular congestion of these parts.

The oil or unctuous soft solid which is now ascertained to be one of the constituents of healthy blood,* is liable to morbid increase under various forms of disease. Morgagni cites two cases of malignant fever in which the serum was milky. Hewson, besides enumerating instances to be met with in authors, gives three cases sent him by medical friends: one of amenorrhœa with dyspepsia and vicarious discharge of blood by vomit and stool; another of violent and continued epistaxis, and a third of dyspepsia with slight asthma. In all three cases there were symptoms of plethora; but milky serum is by no means necessarily connected with this state. The most marked instance that I have met with was in a case of diabetes, where bleeding was several times repeated at long intervals, and on each occasion the same morbid

* See a paper by M. Vauquelin, in the 16th vol. of the Ann. de Chimie, new series, p. 363.

† See Med.-Chir. Trans. vol. xii. p. 89.

‡ Med.-Chir. Trans. vol. xvi. p. 296.

* Med.-Chir. Trans. vol. xvi. p. 46.

condition of serum was observed. This was quite opaque, and nearly as white as milk; and on standing for a few hours, a film of mattter resembling cream covered the surface. The clot could not be seen when it was scarcely a tenth of an inch beneath the surface. It had a firm, very thick, white coat of fibrine, and the red particles were almost diffluent beneath. The patient, a female, could not be called plethoric, having been the subject of her emaciating complaint more than a year and a half. Milky serum, though of a far less marked character, having occurred in persons who have been bled shortly after making a hearty meal, the notion has been entertained that it is owing to the passage of liquid chyle into the circulation. This was Haller's opinion, while others have attributed its appearance to admixture of fat. To the former notion it may be objected, that whereas it is certain that the milky appearance of serum is owing to the presence of oily particles, it is very doubtful, from the discordant opinions of eminent chemists, whether the chyle contains more oily matter than the blood itself. Berzelius, indeed, makes its solid part to consist of more than twenty-one per cent. of fat, and Raspail considers it as differing little from milk. Prout, however, whose analysis is adopted by Turner, only admits an unappreciable trace of oily matter in chyle, and makes its composition differ little from blood except as respects the absence of red particles. In milky serum the oil exists in superabundance at the expense of the albumen, which, in all the specimens I have examined, has been remarkably deficient in proportion, its specific gravity varying from 1·019 to 1·024. This circumstance naturally leads to a question whether this oil may not owe its origin to some chemical change in the albumen itself, of which it seems to supply the place. The 'remarkable blood' described by M. Caventou,* and alluded to by M. Raspail, † which was evidently nothing more than blood with milky serum, affords additional ground for supposing that such a change takes place. "This blood issuing from the vein was turbid, of a pale dirty red colour, and became marled and of a whitish red as it cooled in the basin, and some drops which fell on the floor assumed this colour in a few seconds, and looked like drops of chocolate made with milk. After half an hour a coagulum of moderate size was formed in it, which floated in a large quantity of a white opaque fluid exactly like milk." Raspail, who had evidently never seen a marked example of milky blood, gives the following fanciful explanation of the appearance. "Under the influence, or in the absence of one of the causes which together produce the circulation, an acid had been formed, which, saturating the alkaline menstruum of the albumen, had caused it to coagulate. Now this irregular coagulation could not take place without disguising the colour of the blood and rendering it rose-coloured, while it would give the serum the appearance of milk." If the albumen had really been coagulated by an acid, a distinct clot would not have been formed by it, but a curdled precipitate; nor would the serum have borne any resemblance to milk. But what is important as confirming my view respecting the conversion mentioned above, M. Caventou, to his great astonishment, could not find any albumen in the milky serum here described. The probability of this change is heightened by the consideration that something analogous must necessarily occur in the formation of true milk, the oil of which, when separated as butter and melted to clarify it from curd, remarkably resembles the oil of milky serum.

* Annales de Chimie, vol. xxxix. p. 288.
† Sect. 941.

The attention of pathologists to the salts of the blood, which, considering the visible effects they produce on this fluid, had been strangely neglected, has of late years been roused by the observations of Dr. Stevens, who certainly may claim the merit of having advanced our knowledge of facts on this subject. It appears that in the last stages of tropical fevers the saline ingredients of the blood are so much diminished that they are no longer capable of giving a red colour to the hæmatosine. The black blood that is found in the heart after death from either the climate fever or the African typhus, remains black even in an atmosphere of pure oxygen, but it instantly changes colour when we add it to a clear fluid that contains even a small portion of any neutral salt. Nor is it in fever alone that this deficiency of salts is observed. Dr. O'Shaughnessy has shewn that it likewise exists in malignant cholera, and it is probable that in sea-scurvy, and in those analogous diseases produced by want and unwholesome nourishment, a similar state occurs.

The saline matters may be in excess as well as in defect, and this is marked by excitement of the circulating system, and either local determinations or general febrile disturbance. The stimulant effect of saline springs has been known time out of mind, while the thirst and heat produced by the too copious use of common salt is in every body's experience. If we couple these facts with the certainty that the neutral salts will pass unchanged through the circulation so as to admit of detection in the urine, we may infer that their superabundance in the bood is not only a possible, but, in all probability, a frequent occurrence. They are occasionally fouud after death deposited in a crystalized form, as was observed by Sir Everard Home, who, in dissecting an aneurismal tumour, found a mass of crystals, which were analyzed by Mr. Faraday, and are stated to have been salts usually met with in the blood.

Having thus concluded such remarks as the present state of our knowledge has enabled me to offer respecting the morbid changes which take place in the separate constituents of the blood, I now proceed to notice some of the more important diseases in which those changes have been observed to occur.

Inflammation.—The usual appearances of blood in inflammatory diseases have already been described in treating of the buffed coat. The crassamentum is commonly supposed to be increased in bulk, but this is somewhat doubtful; and indeed it so much depends upon extraneous circumstances, such as the form of the vessel in which the blood is received, the time allowed for the contraction of the clot, which it is well known goes on for many hours, and even the quantity abstracted, that no accurate deduction can be drawn from its appearance. The collection of the fibrine itself is easily effected, and it will thus be perceived that, under inflammation, it is more abundant than in the normal state. Scudamore has made numerous experiments on the relative quantity of fibrine contained in healthy and diseased crassamentum, and the following short list selected from them satisfactorily establishes this fact.

In 1000 grs. of clot as deduced from eight specimens of healthy blood, average of dry fibrine..........	3·53 grs.
Maximum 4·43, minimum 2·37	
Slight pleurisy, blood slightly buffed	7·05
Pain in the side, ditto......	11·37
Cough	7·24
Acute gout, blood not buffed, firm texture	5·88
Disease not named, clot compact, buffed, and cupped	12·41
Ditto	13·73
Average	9·62

Mr. Jennings, in his report on the blood in the Transactions of the Provincial Medical Association for 1834, likewise gives a table, the result of which is, that in eight cases of inflammation, the proportion of fibrine in the blood was increased from 2·1, which is Lecanu's standard of health, to 9, 8, 11, 6, 5·3, 7, 6·9, 7 ; average 7·525, and that the alkaline salts were diminished from 8·37, the healthy standard, to 4·9, 4·8, 5·1, 4·3, 4·2, 4·4, 4, 5·6; average 4·61.

Among all the varieties of inflammation it is in acute rheumatism where we find the blood most decidedly loaded with fibrine. Owing to the powerful action of the heart and arteries, it is intensely arterial in character, and sometimes issues from the vein with a distinct pulsation.

Fever.—In those fevers which arise from marsh miasmata or from contagion, it is an opinion held by Dr. Stevens, and supported at great length in his work on the blood, that a diseased condition of that fluid is the first in the train of symptoms which occur, and the immediate cause of those which follow. The blood itself, says Dr. Stevens, is both black and diseased even before the attack. During the cold stage it is very dark. When first drawn it has a peculiar smell, and coagulates almost invariably without any crust. There are black spots on the surface of the crassamentum, the coagulum is so soft that it can easily be separated by the fingers, and during its formation a large quantity of the black colouring matter falls to the bottom of the cup. In the hot stage it becomes more red, and, in some cases, it is even florid for a time, but during the remission it is darker in colour than the blood of health, and decidedly diseased in all its properties. In milder cases, the blood which is drawn may coagulate without a crust on the surface; but in the more severe forms of this fever, when the blood was drawn at an advanced period of the disease, a part of the albumen coagulated on the surface of the fibrine, and formed a diseased mass, which in appearance had a greater resemblance to oatmeal gruel than to blood drawn from a healthy person. The serum which separated was also diseased; it had a brownish colour, and in some cases an oily appearance, which is never met with in the clear serum of healthy blood. In the climate or seasoning fever of the West Indies, which is not considered contagious, but a fever of excitement, the blood drawn in the first stage flows from the vein with great force, but is neither cupped nor buffed. It is so florid, being charged with salts which ought to have been removed by the organs of secretion, that it resembles arterial blood. The fibrine coagulates firmly, and in some cases the serum which separates from it has a bright arterial colour, the colouring matter being not merely diffused through, but combined with the serum. During the progress of this kind of fever the blood loses a large proportion of its fibrine and albumen, and becomes so thin that it oozes from the mucous membranes without any abrasion of surface, and in the last stage turns quite black from a diminution in the proportion of its salts.

Such are the appearances which the blood presents in the more severe fevers of hot climates. In this country, at the commencement or stage of depression the blood is dark and tarry, coagulates quickly, and forms a large clot with but little serum. As the stage of excitement advances, the blood becomes thinner and more florid, and flows more freely. Coagulation takes place more slowly, and a buffy crust is frequently formed on the surface of the clot. In the latter stage, when the powers are giving way, the blood becomes thinner, darker, and more dissolved. It scarcely coagulates at all, and is deficient in saline matter, and probably also in fibrine, thus nearly resembling menstrual blood, or the fluid mixture of serum and red particles, already mentioned as often found in the larger vessels after death. Such are the alterations which the blood usually undergoes in the different stages of simple continued fever, but in its more malignant forms, as in typhus, the blood is generally very watery, even from the commencement. As the disease advances, it gradually loses its power of coagulation, and in the last stage seems almost entirely deprived of fibrine.

Magendie has artificially produced an analogous state of blood by injecting putrid liquids into the veins of animals, and the speedily fatal disease which he thus caused had a strong analogy with typhous fever.*

To Dr. Stevens belongs the merit of having especially directed general attention to the circumstance that the saline matter of the blood gradually disappears in the progress of fever, and is almost entirely lost in its last stage. This he ascertained by direct experiment,† and his facts have since been confirmed by Jennings, who in the interesting report already alluded to, gives an analysis of the blood in six cases of continued fever, in which the

* Journal de Physiologie, tom. iii. p. 83.

† On the Blood, &c. page 209.

alkaline salts were found diminished in the following proportions:—

In healthy serum, according to Lecanu, salts.............................. 8·10
In the serum of a male, aged 31, first day of fever, salts 4
Ditto ditto aged 34, first day of fever, salts........................ 5
Ditto female, aged 14, fourth day of fever, salts .... 4·2
Average of three other cases .... 4·4

Scurvy.—It seems to be the universal opinion of those who have seen and written on scurvy, that it owes its origin to a morbid change in the fluids, and especially in the blood; and even those who have been the most strenuous opposers of the humoral pathology in general, among the most celebrated of whom we may reckon Willis, Hoffmann, Boerhaave, Cullen, and Sir John Pringle, have made an exception in favour of this disease. Notwithstanding this general belief there has been no attempt up to the present time at any chemical examination of the properties of scorbutic blood, and we have only the general observation made by the surgeons of Lord Anson's expedition, (Messrs. Ettrick and Allen,) that in the beginning of the disease it flows from the arm in different shades of light and dark streaks; that as this advances, it runs thin and black, and after standing turns thick and of a dark muddy colour, the surface in many places being of a greenish hue, without any regular separation of its parts; that in the third degree of the disease it is as black as ink, and though kept stirring in the vessel for many hours, its fibrous parts have only the appearance of wool or hair floating in a muddy substance; and that in dissected bodies the blood in the veins is so fluid that by cutting any considerable branch, the part to which it belongs may be emptied of its black and yellow liquor, the extravasated blood being precisely of the same kind. The prevalence of scurvy where there has been a long-continued use of salted provisions has given rise to the supposition* that the salt itself actually finds its way into the circulation, and acts as it is known to act on blood out of the body by preventing its coagulation. This, however, is very evidently not the case, first, because salt provisions are not necessary to its production, since scurvy has often made its appearance where no salt provisions were used; as, for instance, in the Milbank Penitentiary in 1819, where the diet consisted of pease, barley soup, and brown bread; and, secondly, because the appearance of the blood, especially as the disease advances, is exactly the reverse of what it would be on the addition of salt, which, instead of making it black, and causing it on standing to become thick, muddy, and of a greenish hue, would impart to it a fine scarlet tint that would remain permanent until it began to putrefy. Since the modern advances in animal chemistry, opportunities for examining the blood in true scurvy have been very rare; and it is therefore the more to be regretted that Drs. Latham and Roget, philosophers every way so competent to determine the precise morbid changes which it undergoes, did not, when they had it in their power, make a particular examination of it. Venesection, it seems, was practised at the Penitentiary in a few cases, but nothing is stated respecting the appearance which the blood assumed.* The description of Lord Anson's surgeons does not by any means apply to the blood which is found in purpura hæmorrhagica, a complaint that was, prior to the appearance of Dr. Bateman's work on diseases of the skin, generally considered closely allied to scurvy. In two cases of purpura related by Dr. Parry,† of Bath, blood drawn from the arm exhibited a tenacious contracted coagulum covered with a thick coat of lymph; and in one instance which occurred under my care, where the patient, a man of forty-five years of age, had most of the symptoms of sea-scurvy, such as general cachexia, with anasarca of the lower limbs, great depression of spirits and prostration of strength, extensive ecchymosis on the trunk and the extremities, fetid breath and extravasations of blood from the gums, the stomach, and the bowels, as well as from a large foul ulcer on the leg; a copious venesection demonstrated that the blood had not in any degree lost its crasis, the crassamentum being covered with a thick buffy coat, and having as much firmness as is usual under the existence of such a state. It is proper to observe that Lind's description of the blood in scurvy differs from that of Lord Anson's surgeons, as he found it generally either natural or buffed.‡

Jaundice.— In jaundice the blood, both arterial and venous, is tinged with bile, and this is apparent not only in the serum, but still more strikingly in the crassamentum, provided it be covered with a buffed surface. If this be removed and dried in a state of tension, it exhibits a deep yellow hue, particularly when viewed by transmitted light. Although the bile is thus rendered very visible in jaundiced blood, yet, owing to its combination with albumen, which defends it from the action of acids, it is difficult of detection by chemical re-agents, so that many chemists of eminence have sought in vain to ascertain its presence. Lassaigne, however, succeeded in demonstrating that the colouring matter of the bile is really to be found in the circulation, and Berzelius tells us that Collard and Martigny pretend to have discovered even the resin of bile in jaundiced blood. M. Lecanu has more recently confirmed these facts, and Mr. Kane has verified his results.§ To the medical inquirer who does not follow the minutiæ of animal chemistry, the identity of the colouring matter in the serum of jaundiced

* Jennins's Report.

* Account of the Disease lately prevalent at the General Penitentiary, by P.M. Latham, M.D. 1823, p. 39.

† Edinburgh Medical and Surgical Journal, vol. v. p. 7.

‡ Lind on Scurvy, page 512.

§ Dublin Journal, vol. ii. p. 346.

blood with that of the bile itself will be rendered sufficiently evident by adding to it an equal quantity of sulphuric acid diluted with twice its bulk of water. The serum will thus change its yellow hue for the characteristic green colour of acid bile. Experimentalists have failed in producing this effect, being probably misled by having found that the small proportion of acid which is required to strike a green colour with urine charged with bile, produces no such effect when added to jaundiced serum.

Disease of the kidney.—In those organic diseases of the kidney which are characterized by anasarca and the passing of urine coagulable by heat and acids, the albumen of the blood is more or less deficient in proportion; and this is marked by a corresponding diminution in the specific gravity of the serum. In a letter to Dr. Bright, published in the first volume of that author's Reports of Medical Cases, page 83, Dr. Bostock states, in reference to the blood in these diseases, that the crassamentum was for the most part covered with a thick buffy coat, and was generally of a firm consistence. The appearance of the serum was more varied. It was occasionally turbid, and upon standing for twenty-four hours a white creamy substance rose to the surface; but no proper oily matter could be detected in it. On exposing it to heat, it coagulated in the ordinary manner, except that the coagulum seemed to contain an unusual number of cells, and that a greater quantity of serosity separated from it. "I think I may venture to say," adds the writer, "that the serum generally in these cases contained less albumen than in health, although I am not able to state precisely the amount of this difference. The serosity which drained from the coagulated albumen on being evaporated was found to consist in part of an animal matter possessing peculiar properties which seemed to approach to those of urea; it was partially soluble in alcohol, and was acted upon in a somewhat similar manner by nitric acid."

The above remarks were made on specimens of blood furnished from time to time by Dr. Bright. The number is not stated, nor was the specific gravity of the serum taken. Dr. Bostock gives a case, however, (page 85,) where, after stating that the crassamentum was remarkably buffed and cupped, he adds, "The serum was also worthy of attention, as taken in connexion with the state of the other fluids. Its specific gravity was almost exactly the same with that of the urine, being no more than 1·013, which I believe to be lower than had ever occurred to me in the numerous experiments which I have made upon this substance. We have here, therefore, an example of blood exhibiting a very great deficiency of albumen, at the same time that we observe the mode in which it passes off from the system by means of the kidney, while this organ has its appropriate office of secreting urea nearly suspended. I regret that I did not attend particularly to the specific gravity of the other specimens of dropsical serum which you sent me. From some incidental remarks in my notes, I suspect that its specific gravity would have been found lower than ordinary; but it is a circumstance which I shall be anxious to ascertain when any opportunity occurs." This suspicion is completely confirmed by other cases that have occurred to myself, in which the fact was also established beyond doubt, that the animal matter found by Dr. Bostock in the serosity was not merely an approach to urea, but that principle itself possessing all its usual characters. The following may serve as an example of light serum.

William Squires, aged 54, labouring under organic disease of the kidneys and chronic bronchites with anasarca, had for many months voided urine which coagulated on the application of heat or the addition of nitric acid.

The specific gravity of his blood at 88 Fahr. was 1·041
Do. Serum at 68 1·021
healthy standard 1·030.

This blood contained in 1000 parts,
3·845 fibrine :
healthy standard 2·1 to 3·56
55·000 albumen :
healthy standard 65 to 69

In this case 100 grains of urine contained 6·666 albumen. There was consequently nearly one eighth as much albumen in the urine as in the blood, and the patient lost as much of that constituent daily, as if he had been bled to the extent of four ounces.

The following cases are from notes with which I have been favoured by Dr. G. H. Barlow, who has devoted much attention to the examination of the blood and urine in this disease.

No. 1. A patient affected with general anasarca—Urine copious, clear, pale, coagulable by heat and nitric acid : specific gravity 1·011. Blood cupped and buffed, serum milky : specific gravity 1·019.

No. 2. Man aged 48, anasarcous—Urine dingy brown, natural in quantity, acid, coagulable; specific gravity 1·017, contained 4½ per cent. of albumen. Serum of the blood, specific gravity 1·013.

No. 3. A man who was found on post-mortem examination to have granulated kidneys. Urine reddish brown, very scanty, coagulable; specific gravity 1·008. Blood cupped and buffed; specific gravity (of the whole blood) 1·037.

In my paper on the blood in the Medico-Chirurgical Transactions, vol. xvi. I have stated the case of a woman forty-eight years of age, who for ten weeks had complained of pains in her loins, anasarcous swelling of her legs, and general debility, and who passed urine which was in a high degree coagulable. I examined her blood, and found it to contain 0·43 per cent. of fibrine, and only 1·61 per cent. of albumen. The specific gravity of the serum was 1·020 at 60° Fahr. In that paper I have also observed that in several cases marked by coagulable urine, I have examined the specific gravity of serum with which Dr. Bright has furnished me, and have always found it much below the healthy standard.

It is not, however, in this complaint exclusively that the albumen of the blood will be found deficient in proportion. In other dropsical affections it will sometimes happen that a proportion of albumen more than equivalent to the fibrine effused will disappear from the circulation. Eleven days after tapping a young woman, in whom ascites had supervened upon rheumatic affection of the heart, she was observed to be filling again very fast. A few ounces of blood were taken from the arm, and this blood was found to contain 0·319 per cent. of fibrine, and only 3·51 per cent. of albumen. Her serum had a specific gravity of 1·023.

The experiments of MM. Prevost and Dumas (Annales de Chimie, vol. xxiii.) which have since been repeated by Gmelin and Tiedemann (Poggendorff's Annalen), prove satisfactorily that urea exists in the blood after the kidneys have been extirpated, and consequently that it is not formed, but merely abstracted by those organs. So long, however, as the kidneys act, we cannot expect to find it, since it is removed from the circulation as fast as it is formed, and never exists in any considerable quantity.

In these cases of diseased kidney a result analogous to that which follows extirpation occurs, for while that organ is permitting albumen to pass through it unchanged, the urea which it should separate is very generally if not always found in the blood. This I have proved in repeated instances, and it is now so generally admitted from the experiments of Prout, Christison, and others, that it is scarcely worth while to cite cases. Dr. Bright, vol. ii. p. 447, alludes to several specimens of serum from patients under this disease, which he had sent me for examination, in some of which I did, and in others I could not detect urea. In one very remarkable instance of a young woman, the albuminous state of whose urine constantly existed for above three years, the urine contained less than one-third of the normal proportion of urea, while about one per cent. of albumen supplied the deficiency. The serum of the blood was, as I have already remarked to be usual in this disease, of very low specific gravity, being only 1·021. The quantity of albumen in 1000 grains amounted, after careful drying, to only 50 grains instead of 78 (Lecanu's healthy standard), and it contained fully as much urea as the urine itself, the 1000 grains yielding nearly 15 grains of that principle.

It may not be out of place here to observe, that in this disease not only does the blood itself contain urea, but all those effusions also which are formed from it, and which take place in the different serous cavities. I have repeatedly detected urea in these cases in the serous effusion into the ventricles of the brain; and Dr. Barlow found it in one case, 1st, in abundance in the ventricles of the brain; 2dly, scantily in the effusion into the pleura and pericardium; and 3dly, in abundance in the peritoneum. In a second case of a similar nature urea was obtained in abundance from the fluid of the pericardium. In a third the effusion collected after death from the pleura of a man who had suffered from general dropsy and mottled kidney, yielded a very satisfactory specimen of urea.

I have dwelt at some length on this subject, as it is only of late years that the attention of the medical world has been drawn to it through the writings of Dr. Bright, and still more recently that the morbid changes presented in the blood have been investigated.

Diabetes.—In this complaint the blood unquestionably undergoes some material change, although its nature has not hitherto been very successfully investigated. This may be inferred from the great length of time during which it is capable of resisting putrefaction, a circumstance first noticed by Rollo, and which, though doubted by some authors, I have had opportunities of confirming in several instances. Nicolas and Gieudeville* have observed that it contains an increase of serum and very little fibrine, but this is not borne out by my own experience as deduced from many specimens of diabetic blood which I have examined; neither can its antiseptic qualities be attributed to any deficiency in the proportion of azote, for Dr. Prout, who has made accurate experiments to determine this point, has found it not to differ in this respect from the standard of health. The most eminent chemists both abroad and in this country have endeavoured in vain to detect sugar in diabetic blood. Dr. Wollaston ascertained that the smallest portion of saccharine matter added to serum previously to its coagulation by heat, prevents the subsequent crystallization of the salts it contains, yet that in diabetic serum those salts crystallized with the same facility as in that procured from a person in health. The same reasoning as that which has been adduced to prove that urea may be formed in the blood, although it is not to be detected there while the kidneys perform their office, will also apply to the existence of sugar in the blood of those affected with this disease. I am not aware that the arterial blood has been made the subject of experiment, and yet it is possible that it might exist in the arteries alone, for we have only to suppose it to enter the circulation with the chyle, and after having been carried through the lungs, the left cavities of the heart, and the aorta, to be again withdrawn from the circulation by the kidneys. I do not pretend, however, that this supposition carries with it any degree of probability.

Cholera.—There is no disease in which the blood undergoes more remarkable changes than in malignant cholera; not indeed in the incipient stage, as affirmed by Dr. Stevens, but in direct proportion to the intensity and duration of the collapse. In appearance it is thick and dark, bearing a strong resemblance to treacle or tar. It is of high specific gravity, the serum varying from 1·040 to 1·045 at 60 Fahr.; and according to M. Lecanu, the solid matter which it contains is sometimes double that of the healthy proportion. Most of its physical characters are satisfactorily accounted for by its analysis, which has been accurately made by several eminent chemists, among whom we may

* Annales de Chimie, vol. xliv. p. 69.

mention Dr. Turner, M. Lecanu, and Dr. O'Shaughnessy. Cholera blood, according to these authorities, contains less water and more albumen and hæmatosine than healthy blood, and its salts are in unusually small quantity, or almost entirely wanting. Dr. O'Shaughnessy, who has detected urea in cholera blood, states that the summary of his experiments denotes a great but variable deficiency of water in the blood of four malignant cholera cases; a total absence of carbonate of soda in two; its occurrence in an almost infinitessimally small proportion in one; and a remarkable diminution of the other saline ingredients: lastly, the microscopic structure of the blood and its capability of aeration are shewn to be preserved. The cause of the dark colour of the blood in cholera is a point which we are told by Dr. Turner is by no means decided. Dr. Thomson and Dr. O'Shaughnessy are at variance on the question of its susceptibility of arterialization. Dr. Stevens rather unphilosophically makes its dark colour to depend *primarily* on the poisonous cause of contagion, yet attributes it also to a deficiency in the proportion of saline matter. It is probably not owing to either of these causes, but to a defective circulation through the lungs, from which the blue livid tint frequently observed over the surface of the limbs likewise originates. The corresponding diminution of animal heat gives countenance to this supposition.

Chlorosis.—Among other changes which occur in the progress of chlorosis, there is none more constant than an impoverished condition of the blood, which is thin, light-coloured, and weakly coagulable, being deficient in fibrine, and still more so in the proportion of the red particles. To the latter cause is to be attributed the diminished temperature of the surface, together with the universal pallor and waxy appearance which those who are the subjects of this disease generally exhibit. The deficiency of colour in the catamenia, and the pale stain which hæmorrhages from the nose leave on linen, are also referable to the same cause. In aggravated cases, if blood be drawn from the arm, the crassamentum is observed to be of a pale rose colour, and small in proportion to the serum. We have to regret that in this, as in most other cases of morbid blood, pathologists have contented themselves with a general observation of facts without attempting to investigate them with that degree of precision which can alone lead to a further advancement of our knowledge respecting their causes. The only analyses of chlorotic blood of which I can find a record are given by Mr. Jenkins in two well-marked cases of chlorosis; the one of a girl aged fifteen, the other of a young woman aged twenty-one. In these the blood contained 871 and 852 parts in a thousand, of water, respectively, instead of 780, the healthy standard; and the colouring matter amounted to 48·7 and 52, instead of 133. The albumen and salts were in the usual proportions.

Melanosis.—Although it would be foreign to my present object to treat of the various morbid products which may be supposed to have their origin in a diseased state of the blood, yet there is one which seems so evidently to be the result of an accidental change in that fluid, that it must not be passed over without a brief notice. The similarity of chemical composition in the blood and in the matter of melanosis is such as to leave little doubt that the material of which the latter is composed has its origin in the circulation, and is afterwards deposited in the various parts in which it is found. The different analyses of melanosis, says Andral, all concur in one important point. They all shew that the accidental production called melanosis is formed of the different elements of blood, and especially of a colouring matter which more or less resembles that of the blood, but which is, nevertheless, not identical with it. M. Foy, in his analysis, calls this altered cruor. Dr. Carswell, to whom we owe the most detailed and best account of melanosis which we possess, states that he has fixed its seat in the blood, not only because it is seen there, but because his anatomical researches shew that it is there formed. He makes a grand division of melanosis into true and spurious; the former of which occasionally makes its appearance in the circulating system, a fact which is well established, while the latter is more decidedly the result of chemical action. Whenever healthy blood comes in contact with an acid, whether in or out of the body, its colour changes from red to brown or black, in proportion to the strength and abundance of the acid employed. It is to this cause that we are to attribute the appearance of brown or black ramifications, patches, or points, as observed after death in the stomach and intestines. To this cause also are owing the accumulations, during life, of black pitchy matters in the alimentary canal, and it is by the acidity of the black vomit and its power of reddening litmus paper, as we learn from Dr. Stevens, that it can alone be distinguished from blood rendered black by defective decarbonization or the absence of saline ingredients. Where a hæmorrhage occurs, whether by the rupture of a large vessel or by a general oozing from the mucous membrane into the stomach or bowels, we shall find the fluid ejected assume the appearance of red blood or of brown or black matter, according to the presence or absence of the gastric juice in an acid state. Upon this almost accidental circumstance, then, will it depend whether we are to designate the disease hæmatemesis or melæna, there being in reality no essential difference between the two diseases. The black discolouration of blood which occurs whenever it becomes stagnant from retarded or interrupted circulation, will, by those who follow the views of Dr. Stevens, be attributed to a similar cause. According to that author it is the presence of carbonic acid which acts like other acids in rendering venous blood dark, and it is its abstraction by oxygen which, combined with the action of the saline matters it contains, restores it to its scarlet hue.

The foregoing are among the more prominent diseases in which the blood has been observed to undergo changes either directly cognizable by our senses, or discoverable by those chemical and mechanical means which we are enabled to call to our assistance. There are, however, other morbid conditions the existence of which is equally certain, although their essence is of such a doubtful nature that it defies detection by the coarse instruments and the limited skill which man, in the present state of his knowledge, is enabled to employ. In the exanthematous diseases the blood partakes of the general disorder of the system. Dr. Home of Edinburgh* succeeded in reproducing measles by inoculation with blood drawn from a superficial vein in one of the patches of eruption which cover the skin in that disorder; and though others have failed in this experiment, it has been successfully and often repeated by Professor Speranza of Mantua. Pregnant females affected with small-pox, or even exposed to its virus, though they may have had the disease, have often imparted it to the fœtus in utero,† and syphilis has been communicated in the same manner. Professor Coleman has proved by experiment that the blood of a glandered horse will impart glanders if infused into the veins of a healthy animal. Dupuy and Leuret have thus produced malignant pustule; transfusion of the blood of a mangy dog has produced mange in another; and, according to Dr. Hertwich of Berlin, the blood of a rabid animal will by inoculation communicate the disease. A remarkable instance is related by Duhamel, in which a butcher became affected with a malignant pustular disease in consequence of having put into his mouth the knife with which he had slaughtered an over-driven ox. Another individual lost his life from sphacelus of the arm in consequence of a wound in the palm of his hand, accidentally inflicted by a bone of the same animal; and in two women who received some drops of its blood, the one on her hand, the other on her check, inflammations ensued which rapidly terminated in gangrene.

Although in all these instances there can be no doubt that the blood was in a poisonous state, there is no reason to suppose that this could have been foretold by any thing remarkable in its appearance or sensible qualities. Scarcely more successful in general has been the search for extraneous poisons, which nevertheless have appeared from collateral circumstances to have entered the circulation, or have even been purposely introduced into it. Dr. Christison‡ has cited a sufficient number of cases where poisons swallowed have been afterwards found in the blood, to shew that we must not infer their absence from our inability in most cases to abstract them in a separate form; and he further demonstrates how erroneous such an inference might be by stating that Dr. Coindet had himself, after destroying a dog in thirty seconds by injecting 8½ grains of oxalic acid into the femoral vein, endeavoured in vain to detect any portion of it in the blood of the iliac vein and vena cava collected immediately after death, although it is highly improbable that it could have passed off by any of the secretions in so short a time.

The chief obstacles by which we are opposed in such researches are minuteness of quantity and decomposition. When only a few grains of a poison are absorbed, and thence diffused not only through the whole mass of circulating blood, but likewise among all the various tissues and solids of the body, being moreover carried off by the kidneys, perhaps nearly as fast as they enter by the circulation, it cannot be matter of surprise, however delicate our tests may be, that they are seldom to be met with even where still retaining their chemical characters. When we consider, however, that reagents which produce a change of properties in those bodies with which they are brought in contact do probably themselves undergo a corresponding change, we shall readily perceive that our difficulties will be still further increased on this account.

The products of diseased action, and especially pus, have been often met with, as well in the arteries and veins, as in the cavities of the heart; but it yet remains a matter of doubt whether these are actually formed in the blood, or whether, as seems to me more probable, they are not rather carried into the circulation from other parts in a degenerate or diseased state, or are the products of inflammation in the lining membrane of the bloodvessels themselves.

With respect to those cases where worms and insects are said to have appeared in the blood, whereof many are recorded, some are referrible to the head of false polypi, the shape of which has misled the observer, others to deception or the accidental presence of insects or their ova in the receiving vessel; and though we cannot deny the possibility that parasitical animals may exist in the fluids as well as in the closed cavities and solids of the body, yet we require better evidence than has yet been adduced to confirm our belief in the existence of entozoa in the circulating current. In a recent case brought forward by Mr. Bushnan,* and learnedly illustrated by that gentleman, it would, I confess, have carried more conviction to my mind, had he himself watched the blood from the moment of its quitting the vein until the larvæ which he describes were seen swimming in its serum. In such extraordinary cases the mind is not satisfied with anything short of moral certainty.

From what has been set forth in the foregoing pages, it will be perceived that our knowledge on the subject discussed in them yet remains extremely defective. We learn, indeed, that under the existence of disease the different constituents of the blood are liable to morbid increase or diminution as well as to certain alterations in their sensible qualities, hitherto less accurately examined; that

* Duncan's Medical Commentaries, vol. xix. 213.

† Edinb. Med. and Surg. Journ. for April 1807. Med.-Chir. Trans. vol. i. p. 272.

‡ Christison on Poisons, p. 14.

* History of a case in which animals were found in blood, &c.

there are instances in which principles not usually met with in the healthy circulation may be detected in it, and others where those which are always present in a state of health do nearly if not altogether disappear. But that which still remains unknown, and to which it is of the highest interest and importance that our investigations should be directed, is the connexion that these morbid changes have with the diseases which they accompany; the position which they occupy in the relation between cause and effect. Perhaps our present information is not sufficiently minute to give fair expectations of any considerable advances being made in this line of inquiry; for when we contemplate the variety of materials for the formation and removal of morbid as well as of healthy secretions and structures, which are stealing unperceived along the vital current, we are forced to confess how small is the sum of all we know compared with that of which we are still ignorant, and how ample is the harvest which yet remains to be gathered by future labourers in this field of research.

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(*B. G. Babington.*)

BONE, (general anatomy in the normal state.) Gr. ὀστέον. Lat. *os*. Fr. *os*. Germ. *der Knochen*. Ital. *osso*. The important offices fulfilled by bone in the animal economy, and its almost imperishable nature, could not but give it importance in the eyes of the philosopher; whilst every language bears testimony to the high place it holds in popular estimation. We see it forming a framework to give shape and support to the body, cases and cages to protect the more delicate organs, levers by which locomotion is performed and force exerted. Again, we find it, among the tombs, successfully resisting those destructive agents which a century before reduced the softer portions of the body to dust; and we speak of laying our bones in the grave as if they constituted the essential element of our frame.

We propose to treat of the general anatomy of bone under the following heads, viz.—1. its physical properties and intimate structure in man: 2. its periosteum and medulla, and its organization as a part of the living system: 3. its chemical composition: 4. its peculiarities in other animals.

1. *The physical properties and intimate structure of bone in man.*—The most remarkable property in bone, and that which first arrests attention, is its extreme *hardness* compared with other parts of the system. It is, indeed, the only substance in the body which deserves to be called hard; all others are more or less soft, and are consequently destitute of that resistance and firmness by which bones are so admirably adapted for the offices they have to fulfil in the animal machine. The hardness usually increases with age. It varies a little in different situations, and depends, as we shall see, on the earthy matter which enters largely into the composition of the bones.

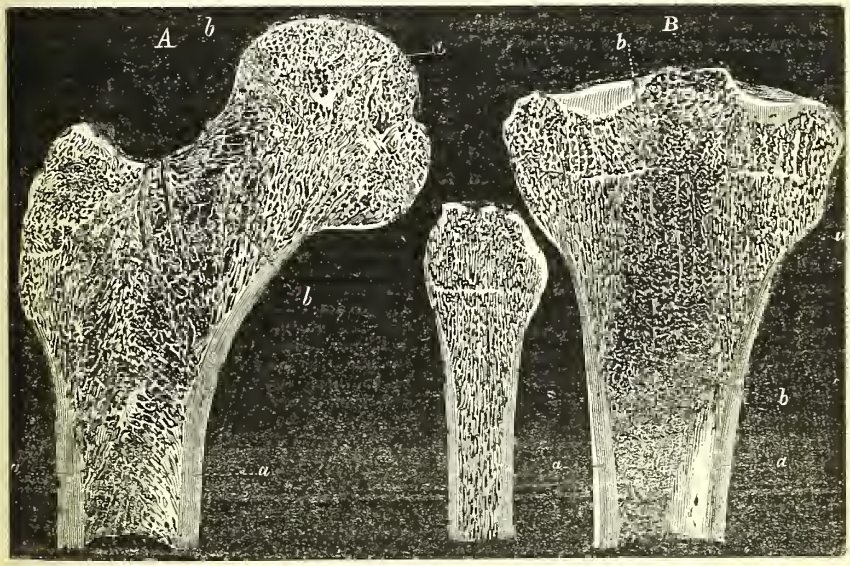
The *colour* of bone in the living person is a pale-rose colour, inclining, in early life to red, in old age to a yellowish white. Bones assume a beautiful white when macerated and deprived of the oily and sanguineous fluids which pervade them. The *specific gravity* of fresh bone is greater than that of any other animal substance. Bone is opaque or only slightly diaphanous. Bones are flexible and elastic. We find that the ribs may be bent and afterwards recover their form perfectly; every schoolboy, indeed, knows the value of a horse's rib as a bow. This elasticity frequently saves them from fractures, and lessens the shock which would otherwise be communicated to the nervous centres and delicate structures they defend. It is possessed by every bone and may be demonstrated in the oldest and most rigid by cutting them into thin slices.

Shape.—Bones assume every variety of shape as might be expected from the use made c them in so complicated a piece of machinery as the skeleton. These varieties have been reduced by anatomists to four classes, viz. 1. the *long* or *cylindrical;* 2. the *broad* or *flat;* 3. the *short or thick;* and 4. the *mixed* or *irregular* bones. The *long* bones are distinguished by their length, which greatly exceeds their other dimensions. They are to be found only in the extremities, and are adapted for locomotion and for supporting the weight of the body. They are never exactly cylindrical, being always contracted in the middle or *shaft*, and enlarged at each end; and their transverse section is oval or triangular, never round. The *broad* or *flat* bones are thin, generally arched, and fitted to protect delicate organs; we find the best specimens of them in the cranium. The *short* have nearly equal length, breadth, and thickness; they are seen in the carpus and tarsus. The *mixed* or *irregular* bones are usually classed with the short, but it is more convenient to separate them: the vertebræ are good examples of these. The ribs and bones of the pelvis may also be ranged with them, combining the characters of two of the preceding classes. Each of these divisions exhibits certain peculiarities of structure to which we shall allude hereafter.*

If we prepare bones by careful maceration and drying, and then saw them through, or, what is better, fracture them with a smart blow of a hammer, we observe the density of texture to differ very much in different portions. The outer part is generally much more dense and close than the interior, and is called the *compact, vitreous*, or *cortical substance*. The interior, open and areolar in its appearance, is the *spongy, cancellated*, or *reticular* substance. These two are arranged in a peculiar manner in each class of bone. In the *long* there is a considerable thickness of compact substance in the shaft, surrounding a cavity, and but little of the spongy, whilst towards the ends the compact gradually becomes thin as paper, the spongy increasing in quantity and filling up all the interior, as if formed by the expansion of the compact tissue (*fig.* 186, *a*). In the *flat* bones the compact substance is formed into two plates with a thin stratum of spongy substance called the *diploë* between (*fig.* 186, *b*). In very thin bones the diploë is often absent. The *short* bones are spongy throughout, with a thin layer of the compact tissue on the surface; they are like the extremities of the long bones: and the *irregular*, resembling in shape two or more of the former classes, have a corresponding arrangement of the two tissues.

A vertical section of three long bones is represented at *fig.* 186, where A is the head and neck of the femur, and B the upper extremities of the tibia and fibula: *a* indicates the compact tissue; *b* the reticular; at *c* it may be seen how thin is the layer of compact tissue covering the head of the femur.

Fig. 186.



In the shaft of the long bones there exists a cavity of considerable size filled with marrow, and called the medullary cavity. This is widest in the centre, gradually getting smaller towards the extremities, where its place is occupied with spongy substance. The interior of this cavity is rough; bony processes project into it, and form a kind of net-work resembling the spongy substance at the ends, but with more open and less regular cells. By some anatomists the term *spongy* is confined to the cellular arrangement at the ends, that in the middle being

* See further particulars respecting foramina, processes, epiphyses, &c. as connected with mechanical contrivance, under the article SKELETON.

denominated *reticular* or *cancellated.* Such a distinction is useless. There is no line of demarcation between them.

At first view a great difference appears to exist between the compact and the spongy substance, but in reality this is not the case. The degree of condensation is the only distinction. The spongy substance would become compact were the sides of its cells pressed together, and the compact would become spongy or reticular were its texture loosened by enlarging the minute cells which may be detected even in it. Such changes actually occur by the processes of absorption and deposition in growing bones. In the perfect bone the cells are compressed towards its middle to diminish its bulk, and thereby to accommodate the bellies of the muscles; and they are expanded at its ends for the purpose of giving security to the joints by a more extensive surface, and allowing more room and power to tendons, &c., whilst the osseous matter in equal lengths of bone, whether at centre or extremity, is of nearly equal weight. The surface of bone in many places presents a striated appearance; and small holes or canals are seen on it especially near the ends of long bones.

Simple inspection of dried and divided bone carries us thus far in the knowledge of its structure. But the question still arises, what is the arrangement of the particles which compose the compact and spongy tissues? Is bone laminated, or fibrous, or cellular? or does it partake of a texture in which these three varieties of disposition are to be found? One might imagine there could be no great difficulty in answering these questions, where bone is so readily procured, so easily preserved, and admits of such varied modes of examination. It can be viewed in the living subject, or after death while fresh, or when prepared by injection, or when all its moisture is removed. It was long ago discovered to consist of an earthy and an animal portion, either of which can be removed, leaving the other undisturbed in its original form. Yet, with all these "appliances and means to boot," anatomists have entertained opposite opinions, and are not yet quite agreed upon the subject. Malpighi, the first author who deserves to be mentioned, thought that bone consisted of fibres and filaments with an intermediate osseous juice: "constat igitur, ossa coagmentari filamentis, et fibris per longum ductis in rete implicitis, quæ affuso osseo succo ferruminantur in solidam densamque ossis naturam." (Op. Posth. p. 47. Lond. 1636.) He also allowed the existence of lamellæ, though he does not put forward its lamellar structure in a prominent way.* Gagliardi adopted his notions of a laminated structure, but made additions, from which Malpighi, at a subsequent period, expressed his dissent. He examined bones long exposed to the weather, or softened by boiling, and concluded that they were formed of plates, (lamellæ, squamulæ, bracteæ,) held together by processes, in the form of nails, the shape and direction of which he minutely describes.* Clopton Havers found bones composed of plates connected by an osseous juice, with pores which ran, some transversely through the plates, others longitudinally through the entire length of the bone.† Leuwenhoeck thought that the filaments of Malpighi were hollow tubuli.‡ Duhamel observed concentric layers as in wood.§ Haller says, "Fibrosum est (os) sive in laminas et fila divisum quæ sulcis separantur."‖ And Monro lays it down that "bones are composed of a great many plates, each of which is made up of fibres or strings united by smaller fibrils."¶ About the close of the eighteenth century the celebrated Scarpa published his work "De penitiori ossium structura," in which he combats former opinions, and asserts that bone is in every part of a cellular or reticular texture. In the first place he shows that we have no proof of its *lamellated* structure; the appearances produced by calcination, the weather, disease, &c. on which former anatomists relied, proving nothing. Calcination is a rude process, and acts with different power on the different parts of the same bone as they vary in density, and divides them irregularly as it happens to overcome their force of cohesion. The same thing may be said of the weather. And exfoliation takes place in the skin, whose

* We are told by an interesting writer that Malpighi compared these lamellæ to the *leaves of a book.* Could this writer have taken "*libri,*" in the following passage, to mean book instead of bark, of which last Malpighi had just been speaking? "*Pari* incremento procedit natura in ossium augmento. Fœtûs ossa, et cranium precipué, filamentorum progressum exhibent; hæc non omnino sibi parallela sunt, et hinc inde breves appendiculas filamentosas promunt, quibus invicem colligata rete efformant *parum a libri natura distans,* cujus potiores areæ et tota fibrarum compages exsudante osseo succo repletur et tumet." Here we have a tissue of fibres and filaments running in various directions, and *forming a net-work not unlike a book!!* From this quotation, indeed, it might be thought that our author entirely denied the existence of plates. However, in the next sentence he speaks of *plana, lamellæ,* and *bracteæ:* "Successivis incrementis nova fibrarum *plana* superinducuntur, quæ præexistenti *lamellæ* osseo agglutinata succo, debitam molem et firmitatem excitant. Patent autem singula *plana* resolutione factâ per longum ossium maceratione; integræ namque osseæ reticulares *bracteæ* evelluntur. In abortibus verò in cranio inchoatum rete evidenter conspicitur."—*Anatome Plantarum.* Op. Omn. p. 19, Lond. 1686.

* "Natura prudens ossiculis eas transfixit." The nails were of four kinds for the outer plates, viz. "perpendiculares acuti, perpendiculares capitati, oblique situati, et inflexi angulum efformantes." The inner plates, forming the spongy substance, differed from the outer, and were of three kinds, the corrugated, the perforated or cribriform, and the reticulated. These had a system of nails peculiar to them: "alia sine cuspide, plurima ramusculos rescissos efformant, nonnulla breviora."—*Anatome Ossium.* Lugd. Bat. 1723.

† Observationes de Ossibus, Auctore Cloptone Havers. Amstel. 1731.

‡ Opera Omnia, Lugd. Bat. 1722.

§ Mém. de l'Academie Roy. des Sciences, 1739, 41, 42, 43.

‖ Opera Minora, tom. ii. Laus. 1767.

¶ Monro's Works, Edin. 1781.

cellular texture no one denies. In the next place he endeavours to establish its reticular texture; 1st, by observations and experiments on the bones of a chick, made during its growth; 2d, by treating bones with dilute muriatic acid, and then putting them in oil of turpentine to render them transparent. In every bone, he says, the net-work was conspicuous. He observed the same in rickets, in exostosis, and in callus; and still more remarkably in the bones of the amphibia, reptiles, and fishes. The conclusion at which Bichat arrived is not very different: "Ces lames osseuses ne me paroissent point exister dans la nature." "Considerons le tissu compact comme un assemblage de fibres rapprochées mais nullement separées par couche."* Blumenbach and Meckel incline to the lamellar arrangement. More recently bone has been submitted to microscopic examination by Mr. Howship, who agrees with Scarpa that the ultimate texture of bone is not lamellated but reticular. He coincides, too, in opinion with Havers and Leuwenhoeck as to the existence of minute longitudinal canals in it; and he adds that the canals communicate freely with each other, and that a fine vascular membrane lines them in the fœtus, where they may be seen projecting into the temporary cartilage during the growth of bone in the form of fibres which are tubular.† Bostock says, "the membrane of bone is composed of plates very similar in their general form to those of the cellular texture, and it is probable that the earthy matter is inserted between these plates, and thus is likewise disposed to assume the laminated structure." And again: "As we may presume that the earthy part of the bone is moulded into its appropriate form by the membrane into which it is deposited, we may judge of the structure of the latter by that of the former, which, from its firmer consistence, it is more easy to ascertain. Now, whether we examine bone during its formation in the fœtal state, or after it has had its membrane destroyed by the action of fire, we find the earth to assume the appearance of fibres, which, when the bone is perfected, have a tendency to a laminated arrangement."‡

It is plain, from the quotations we have made from some of the most distinguished writers on the structure of bone, that all before the time of Scarpa considered it laminated, or fibrous and laminated, while all, after his publication, looked upon it as cellular. In the former, however, we see some intimations of a reticular texture; in the latter we hear of a *tendency* or a *disposition* to a laminated arrangement. If, with these opinions before us, we come to examine for ourselves, I think we shall have no hesitation in agreeing with Scarpa that it is *cellular*. At the same time it must be confessed that the sides of the cells are, in the compact tissue, so pressed together that the appearance of laminæ is often very striking, and, again, that the sides of the cells have, in most places, the appearance of fibres. When the earthy portion is removed by an acid, we can teaze out the membranous portion with a pin, and almost demonstrate the fibres. But a closer examination will show that we have torn the cells and destroyed the true texture. The laminated disposition supposed to be shown by exfoliation, the weather, burning, &c. may all be proved to be deceptive; and, indeed, there seldom can be exhibited a plate, however small, of equal thickness throughout, which has been removed by any of these agents. There is, however, an approach to the laminated arrangement, and every cell is formed of particles which approach to the form of fibres. The longitudinal canals of Havers, Leuwenhoeck, and Howship, probably result from the flattened cells, and may be deceptive appearances in the old bone, or the channels for bloodvessels, &c.

2. *The periosteum and medulla, and the organization of bone as a part of the living system.*

A. The periosteum is a fibrous membrane of a dull white colour. It covers bone on every part of its circumference, except where enamel takes its place as on the teeth, or cartilage as on the articular extremities, or fibro-cartilage as where tendons play, or tendon as on sesamoid bones. The fibres which compose it run in different directions and form a tissue of great strength. On the long bones the greater number of fibres take a longitudinal direction. The superficial ones extend for a considerable length without interruption; the deep are short. All interlace with the ligaments of the articulations, and become inseparably united to them, but there is not, as was formerly imagined, a continuity of fibres from one bone to the other by means of the ligaments; on the contrary, the direction of the fibres in these two organs seldom coincides.

The external surface of the periosteum is in contact with a great variety of parts: muscles, synovial bursæ, mucous membranes, vessels and nerves, rest on it immediately, or are separated from it by cellular tissue, and thus permitted to move freely on it. The other surface is connected to the bone by vessels, and by numerous prolongations which pass into the osseous substance and are lost there. This connexion is weak in early life, and especially in the centre of the long bones; but in the more advanced periods the deeper substance of this membrane becomes identified with that of the osseous tissue; thus its union is rendered more intimate, its thickness diminished and its density increased. The union is so close in old age and even in middle life, that the inner fibres of the periosteum are supposed to be the seat of calcareous deposition, and to be converted into bone.

The vascularity of the periosteum may be easily shown by injection, especially in the young. Its vessels freely anastomose with those of the surrounding soft parts, and there is no point of the external osseous surface

* Anat. Génér. tome iii. pp. 24-6. Par. 1812.
† Medico-Chirurgical Trans. vols. vi. and vii.
‡ Bostock's Elementary System of Physiology, vol. i.

which is not perforated with the communicating branches. Some lymphatics have been discovered in its tissue, but no nerves; however, the diseases to which it is subject, the symptoms to which these give rise, and the changes that follow, leave no doubt of the existence of both. That cellular substance enters into its formation is inferred from some of its morbid phenomena, as granulation; and independently of this argument, on which we do not lay much stress, its external fibres are evidently of a mixed nature, combining common cellular membrane with its own peculiar substance. The proper and essential part is the dense, inelastic, and very resisting fibre, by which it is associated with other fibrous membranes. (See FIBROUS TISSUE.) The older anatomists believed that the periosteum had its origin from the dura mater, and might be traced as one continuous membrane over every bone in the body. Boerhaave asserts (Prælectiones Academicæ) that if we could remove it without rupture, we should have an exact mould of the skeleton with all the joints. Its origin from the dura mater was said to take place through the foramina which transmitted the nerves; there the dura mater separated into two layers, one of which enveloped the nerves as neurilema, the other the bones as periosteum. But there does not appear, on close inspection, to be any actual identity between the dura mater and periosteum, although they are most intimately connected; and there certainly is no continuity of the latter membrane over the joints. It is true that we may, at least in young subjects, after boiling, tear off the articular ligaments with the periosteum, but the tendons come off with it too; and in both cases the fibres are seen to be interlaced, not continuous.

Various *uses* have been assigned to the periosteum, such as modelling the bone in its growth and adding new layers to it, for the further consideration of which we refer to the article OSTEOGENY. It is, moreover, also said to be useful for the purpose of protecting the bone from the impression of surrounding muscles, arteries, &c., and *vice versa*, shielding them from the rough and unyielding osseous substance; permitting the soft parts to move freely without injury; and serving as a centre for the fibrous system in general. This last is, in Bichat's opinion, a most important use; he considers its attachment to bone is more for the purpose of affording a *point d'appui* to the fibrous system than for any office it can fulfil with regard to the osseous system.*

B. *Medulla* or *marrow*.—When a longitudinal section of a long bone is made, we observe a large tubular cavity occupying the shaft, becoming smaller as we recede from the centre, and replaced in the extremities by the spongy tissue. This tube is rounded, not having exactly the triangular form so commonly presented by the bone externally. Its surface is rough, especially near the ends, as if it had originally contained cells which were in some way or other broken up. All this cavity is filled with a peculiar, soft, adipose substance—the medulla *(quasi in medio)*, contained in a membrane of extreme delicacy.

The *medullary membrane*, or internal periosteum as it is often called, resembles the pia mater in structure, being composed of vessels ramifying minutely in fine cellular tissue. Its tenuity is such that some anatomists have doubted its existence, but we have only to look into any well-boiled marrowbone, and we shall no longer doubt. It may be shown too by roasting a bone, or macerating it for some time in a diluted mineral acid. This membrane sends numberless prolongations from its inner surface into the medulla which it contains. It is to these processes that the marrow is indebted for its consistence; they form cells and areolæ which support and maintain the vesicles in which the medullary fat is lodged. They are exquisitely fine, and almost invisible; we lacerate them with a touch. The oily substance of the marrow is not in immediate contact with these cells. It is contained in distinct vesicles, which are beautifully figured by Havers. The vesicles are little bags which do not communicate with each other, but look like a cluster of pearls, as Monro observes. When bones have been long buried or macerated, the marrow often assumes a granular appearance depending on this vesicular arrangement. A fine artery runs to each, ramifies on it minutely, and is the source of its secretion. This vessel may be demonstrated. Each artery has its accompanying vein, and, though we cannot see absorbents and nerves, their presence is inferred from analogy and various phenomena. Marrow is merely a variety of *adipose substance*, and to the article on that subject we refer for the chemical properties and some generalities respecting it.

Marrow is not confined to the medullary canal. It is to be found in the cells of the spongy extremities of the long bones, and in the areolæ of the short. It exists in the diploe of the flat bones, and even in the longitudinal canals and pores of the compact tissue every where. In all these situations a membrane lines the osseous cell or pore, and secretes the contents. The membrane is still finer than that of the medullary canal, and the oil is less consistent. The communication between the membranous lining is kept up by vascular prolongations, not by a continuity of cavity. In the bones of the head we find certain cells, called *sinuses*, which contain air, not marrow. They are distinct from the cells of the diploe, with which they have no communication. There is a free anastomosis between the vessels of the medullary membrane and those of the bone and periosteum everywhere.

Near the middle of the long bones a foramen is observed by which an artery of considerable size passes in to the medullary cavity, where it divides into two branches, one for either end. These extend to the extremities of the canal in a beautiful network on its lining

* Anat. Gén. tome iii. Par. 1812.

membrane. The artery is erroneously called the nutritious vessel of the bone. It is obviously intended for the marrow. A vein is seen to accompany it; and nerves may also be demonstrated.

The medullary membrane is possessed of sensibility. This was long ago shown by Duverney.* According to Bichat it enjoys a very high degree of sensibility in the centre, but much less towards the ends. Anatomists do not agree with him in this observation, nor is it found very sensible in any part. Patients seldom complain of pain when, in amputations, it is rudely lacerated by the teeth of the saw; but sometimes they do complain loudly, and in those cases especially where the operation is performed *below* the entrance of the nerve; in the opposite case the nerve is probably divided with the soft parts, and the sensibility, of course, destroyed.

The marrow and the medullary canal vary much in different periods of life, and under different circumstances. No medullary cavity exists in the cartilage which precedes bone; but Bichat asserts that the membrane is present, filled with gelatine of the same appearance as the rest of the cartilage. An assertion so improbable *a priori*, and so contrary to all observation, seemed to require some proof to support it, yet he offers none. When a cavity is formed at a later period, it is at first occupied entirely by the artery; a membrane soon shows itself which contains a reddish watery substance, of a gelatinous appearance, not fatty: it may be dried away before the fire and will not stain paper. To this the true marrow succeeds, more unctuous and more abundant as the individual advances in years. In subjects, however, which have been wasted by slow disease, and in the very aged, the marrow again becomes watery, though not so red as in the fœtus. In the cells of the vertebræ there never is well-formed marrow. It there remains through life sanguineous and almost destitute of oil.

The use of the medullary membrane seems to be to act as an internal periosteum, or a bed in which the vessels may ramify before they enter the osseous substance. Its destruction to any extent is followed by the death of the bone. But is the adeps contained in it of any use? Doubtless it is to the general system a store of nutriment, which is absorbed, in cases of wasting or marasmus, for the general good; but to the bone itself perhaps it is of no more use than so much of any other soft animal substance would be—it fills a space which in the mechanism of the bone was not to be occupied with calcareous matter. Marrow was lighter than the heavy earth of bone, and could at any time be used for the necessities of the animal. We see young bones filled with a gelatinous fluid, and in birds air takes its place—a proof that marrow is no wise essential to the existence of the *osseous* system. Various other uses have been assigned to the marrow, which will not bear examination. Blumenbach, Haller, and their predecessors conceived that it rendered bones more flexible; but the bones of children, which have little or no marrow, are much more flexible than those of adults. Burning a bone renders it brittle, and this was said to be owing to the destruction of its oily part; but it is occasioned, clearly, by the destruction of all its animal ingredients. Some were of opinion that it contributed essentially to the growth and nutrition of bone and to its union when fractured, but bones are far advanced in growth before it appears at all, and they unite faster in the young than in the old. They unite also readily in birds. Others looked on it as the source of synovia; but the very same objections hold to that supposition, and indeed the two fluids are quite dissimilar.

According to the *law of development*, so generally observed, we find fishes and amphibia, like the human fœtus, for the most part destitute of a medullary canal. The crocodile and other lizards are, however, exceptions. Some of these have considerable cavities. Birds, when young, have an imperfect medulla in all their bones, but at a later period the canal in many of them becomes remarkably developed, and then no longer contains marrow; air takes its place, and fulfils important offices in the economy of the class. In mammalia the internal structure coincides with that of the human bones, except in those species which have fins. These approximate to fishes, and either contain no cavity or a very small one filled with fluid oil. The medulla of carnivorous animals generally is softer than that of herbivorous.

Organization of bone as a part of the living system.—The physical properties of bone are so very peculiar that we cannot much wonder at the mistakes of the ancient anatomists respecting its organization. Some classed it it amongst the bloodless organs; others even supposed it to be destitute of vitality; and superficial observation might countenance the supposition, for no pain is excited by sawing, scraping, or cauterizing a bone; but experiment and observation, analogy and disease, all convince us that it possesses well-developed systems of arteries, veins, nerves, and most probably lymphatics, not differing essentially from those of the soft parts. These are obscured by the presence of calcareous matter, not obliterated. "Scrape a bone, and its vessels bleed; cut or bore a bone, and its granulations sprout up; break a bone, and it will heal; or cut a piece away, and more bone will readily be produced; hurt it in any way, and it inflames; burn it, and it dies; take any proof of sensibility but the mere feeling of pain, and it will answer to the proof."* *Animal* sensibility was unnecessary, it would even be inconvenient; it is, therefore, not to be found, except in diseased bone, where it sometimes exhibits itself too acutely.

The presence of bloodvessels may be shown in various ways. 1st. The colour of healthy

* Mémoires de l'Acad. des Sc. 1700.

* Bell's Anatomy.

bone in the living animal is a pale pink, which becomes much deeper in case of inflammation, whilst a deadened portion puts on a yellowish white appearance. When animals are drowned or strangled, their bones assume a darker hue; and in cholera the colour is so deep, and so thoroughly pervades the osscous tissue, that no length of maceration will remove it. In all these cases the colour obviously depends on the blood contained in the osseous vessels. 2d. It was discovered accidentally by Belchier, in 1736, that the bones of animals fed on food tinged with madder very quickly become red; (a sensible change is produced in young animals in twenty-four hours;) now, whether we explain this, with most physiologists, by saying that the earthy matter is coloured in the blood before it is deposited, or, with Gibson, that it receives its dye in the bone, the presence of bloodvessels is equally necessary to account for the phenomenon. (See OSTEOGENY.) 3d. The most satisfactory proof of vascularity in bone is afforded by injection. A young bone may be completely coloured in this way: the vessels are seen to enter it, and if the earthy part be removed by an acid, they may be followed in their fine ramifications through its tissue.

Arteries are found to enter bone under three modifications. 1st. Numerous small vessels fill the minute foramina, which may be seen in the compact substance every where: 2d, a larger set enter the holes which we see on the short bones, and near the extremities of the long ones: and 3d, about the centre of the long bones considerable branches pass into the medullary canal, and ramify on the medullary membrane. These last have been called the nutritious arteries, a name to which they have no claim: they are destined for the marrow. The two first sets are the true nutritious vessels. All, however, freely anastomose with each other.

The *veins* merit particular notice. They

Fig. 187.

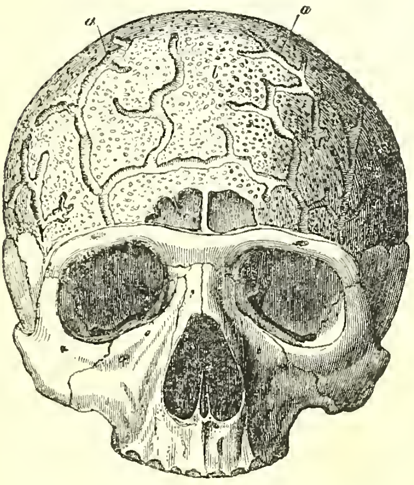
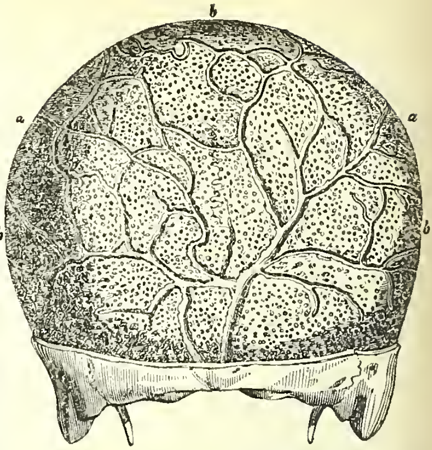


Fig. 188.



have been investigated by Dupuytren,* and their course in some of the bones, especially the flat bones, splendidly figured by Breschet.† In *figs.* 187, and 188, copied from one of Breschet's plates, *a* indicates these veins in the diploe of the cranium: they may be very easily exposed in the cranium by filing away the external table with a coarse file. The first two sets of arteries have no accompanying veins, but with the last there always are veins of a corresponding size. These do not appear large enough to return all the blood; we therefore have others leaving the bone by foramina, which are proper to them, and through which no artery passes. They arise in the spongy tissue by numberless radicles, receive branches like other veins in their course, and, after issuing from the compact tissue by a constricted opening, empty themselves into the vessels of the neighbouring soft parts. The canals through which they pass have a lining of compact substance continuous with the external surface. The veins, while in the bone, have only one coat, the internal, which adheres closely to the osseous canal, and can enjoy no change of size or form. They are, notwithstanding, furnished with valves.

Nerves, doubtless, exist in bone, although we cannot demonstrate them in the osseous substance. But it is not to be supposed that a part so highly vascular would be destitute of nerves. Nerves are seen to enter with the nutritious vessels, and minute filaments pass into some bones, as the frontal. These nerves we may be sure, ramify through every part. The sensibility of an inflamed bone indeed settles the question.

Lymphatics have not been found in the interior of the osseous substance; but they may be seen on the surface.‡ In a tissue such as that of bone it would be no easy matter t

* Propositions sur quelques points d'Anatomie de Physiologie, et d'Anatomie Pathologique. Par. 1803.

† Recherches Anat. sur le système veineux. Par. 1829.

‡ Beclard. Grainger.

exhibit them; even if they existed in great numbers. That they do so exist we have reason to think from the phenomena of mollities, exfoliation, and various other morbid actions, as well as the changes which daily occur in the growth of bone.

3. *Chemical composition.*—When bone is heated to redness in an open fire, some of its ingredients are consumed, and a white friable earth is left behind. Again, if bone be exposed for some time to the action of an acid, it becomes soft and flexible. In both cases the form and size of the original are retained, but there is considerable loss of weight. These facts were well known in the infancy of science; they were too obvious to escape notice; but it does not appear that they were explained before the time of Nesbit in 1736,* nor very satisfactorily then. The existence of an earthy and an animal matter was afterwards proved by Herissant, who showed, by experiment, that acids did not soften the osseous substance as a whole, but removed from it the earthy portion; and that the soft animal matter was always present, but concealed by an earthy "incrustation" of its fibres.† The action of fire on the animal portion was easily explained. Some time after this Gahn discovered that the earth was principally a phosphate of lime; and later chemists, especially Berzelius, have minutely investigated the nature and proportions of these different ingredients. It is now ascertained that bones contain several earthy salts, varying a little in different animals; that the earthy and the animal parts do not always bear the same proportion to each other in the different classes; and that even in the same individual age and situation give rise to varieties.

It was long believed that fat formed an essential part of bone, and that very important properties depended on its mixture with the osseous tissue; but this opinion was quite erroneous. Fat is not always present, and when it is, it invariably belongs to the medulla, which may be looked upon as a distinct structure superadded to bone. It is, as it were, an accidental deposit, and is not to be considered in the analysis.

On removing the fat and periosteum, if we suspend a bone for some days in diluted muriatic acid, the earthy part is dissolved, whilst nearly all the animal portion remains untouched. This last is soft, translucent, and of a yellowish white colour. It is called the *cartilage* of bone. When washed and dried it contracts a little, assumes a deeper colour, though still retaining some translucency, becomes hard and tough, and weighs about one-third of the original bone. This substance yields, on being boiled, a quantity of gelatine, which in young subjects is very considerable, forming nearly all the cartilage, but in the old a soft, white, elastic substance still remains, possessing the figure of the bone. According to Hatchet's experiments this last has the properties of coagulated albumen.* Berzelius,† however, shows that all the cartilage may be resolved by boiling into a clear colourless gelatine, which leaves on the filter only a very small quantity of fibrous substance, the débris of vessels. He does not admit the existence of any albuminous nidus, and even looks upon the gelatine as the product of a decomposition effected by coction on the peculiar cellular basis of bone.

The earth of bone is principally subphosphate of lime; it also contains carbonate of lime and minute quantities of other salts. The following is the analysis, as given by Berzelius, of bone deprived of its oil, blood, and periosteum:—

	Bones of man.	Of the ox.
Cartilage completely soluble in water	32·17	33·30
Vessels	1·13	
Subphosphate of lime with a little fluate of lime	53·04	57·35
Carbonate of lime	11·30	3·85
Phosphate of magnesia	1·16	2·05
Soda, and a very little muriate of soda	1·20	3·45
	100·00	100·00

The proportion of earthy and animal matter is the same generally in man and the other *mammalia.* In *birds* there is more of the animal part which does not perfectly dissolve than in mammalia. In *reptiles* and *osseous fishes* the cartilage of bones approaches in its nature to the substance which, in cartilaginous fishes, is the substitute for bone. This substance is of a peculiar nature; it yields neither gelatine nor albumen, but is more analogous to inspissated mucus than to any thing else.

The earthy salts are not always in the same proportion to each other in different animals. We have seen that they are not the same in man and the ox. Barros gives the following table:—

	Phosphate of lime.	Carbonate of lime.
Lion	95·0	2·5
Sheep	83·0	19·3
Fowl	88·9	10·4
Frog	95·2	2·4
Fish	91·9	5·3

With respect to varieties depending on age and situation, we have a table of the proportions of animal matter and earth as found by Dr. John Davy in several experiments, from which it appears that old bones contain more earth than young ones, and that the bones of the head have a greater proportion than those of the extremities.‡

As to the exact nature of the earthy salts, we have given the results obtained by Berzelius as the latest and most accurate. But it may be right to state that differences of

* Human Osteogeny, by R. Nesbit, M.D. p. 31. Lond. 1736.

† Mémoires de l'Academie Royale des Sciences, 1758.

* Philosophical Transactions, 1800.

† Traité de Chimie. Par. 1833.

‡ See Monro's Elements of Anatomy, vol. i. Edinb. 1825.

opinion exist on this point. Even Berzelius expresses a doubt whether magnesia is met with as a phosphate or a carbonate. We find iron mentioned by Fourcroy and Vauquelin as present in bone. This, according to Berzelius, depends on the red blood which its vessels happen to contain. They also mention silica, alumina, and phosphate but no fluate of ammonia.

4. *Its peculiarities in other animals.*—In the course of this article we have noted the most striking of those peculiarities, so that little need be said under the present head.

The *Radiata*, *Articulata*, and *Mollusca* have coverings which somewhat resemble bone, and are considered by some physiologists as the osseous system of these classes. This opinion will be examined in another place.

Fishes.—*Cartilaginous* fishes have very little earthy matter in their skeleton, so that their bones scarcely deserve the name. They are very flexible, elastic, homogeneous, and semi-transparent, and in chemical composition resemble inspissated mucus. *Osseous* fishes have bones properly so called. They are more flexible than in the higher classes, have no medullary cavity, little of the spongy tissue, and make no approach to the laminated arrangement.

Amphibia have no appearance of laminæ in their bones, nor, with the exception of the crocodile, a medullary cavity. In chemical composition they resemble those of fishes.

Birds have firm, elastic, and thin bones, shewing less of the cellular and more of the laminated disposition than we meet with in the other classes. They have large and well developed cavities, which contain air instead of medulla.

Mammalia.—The bones of the cetacea are coarse and fibrous externally. Within they are spongy or cellular, but the cells assume a remarkable tubular disposition. There is no medullary canal. The bones of quadrupeds do not differ much from those of man. In general they are of a coarser texture, and in some, as in those of the head of the elephant, we find very extensive air-cells.

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(Charles Benson.)

BONE, PATHOLOGICAL CONDITIONS OF.

—The bones, as the foundations of the animal system, as the passive organs of locomotion, required necessarily to be firm and comparatively inelastic and unyielding, qualities which we have seen in the preceding article are imparted to them by the addition to their original animal elements of a saline or earthy substance, consisting principally of phosphate of lime. It is obvious that this difference of structure and constitution must have considerable influence in modifying the diseases to which they are liable, and in giving to the affections of these organs many of their distinguishing peculiarities. In considering, therefore, the phenomena exhibited in the various pathological conditions of the osseous system, not only must the presence of this unorganized earthy substance be constantly borne in mind, but even its relative amount, its abundance or deficiency must command attention. In early life, when the animal material preponderates in quantity, the bones are highly vascular, and comparatively soft, flexible, and springy, and though liable to many serious diseases, they are very apt to escape the effects of injury: fracture is uncommon in infancy; and in childhood the bones, bending rather than breaking, often exhibit that partial fracture which has been likened to a "branch of a tree that yields to an attempt to break it while it still retains its sap."* The powers of repair are commensurate with the extent of vascular organization at this period; fracture is quickly re-united, and its effects so regulated by the subsequent growth of the bone that permanent deformity is a very infrequent occurrence.

But this activity in the osseous system in early life has its evils. The period of youth, between absolute childhood and puberty, is that in which disease is most easily and, therefore, most frequently developed, and although extensive powers of reparation are constantly exhibited in recovery after caries, in reproduction after necrosis &c., still are the operations that lead to these results languid and too often inefficient,—circumstances that may be attributed partly to peculiarity of organization in the structure affected, but perhaps with more propriety to the influence of some general constitutional taint over which medicine exerts but slender control.

The osseous system cannot be considered as having attained maturity until a period subsequent to the age of puberty, most commonly somewhere between the twenty-seventh and thirtieth years. At this time bone is calculated most perfectly to answer its purposes in the animal economy: it is then least liable to disease; and if fractures and other injuries are more frequent, it is only because individuals are now more exposed to them. The effects of these injuries are in general repaired sufficiently well, but if deformity has been produced it will be permanent, because the bone has ceased to grow.

* See a paper on this subject by Dr. Hart, vol. i. Dublin Journal of Medical Science.

As life advances, the osseous system undergoes many obvious alterations. The shape of some bones is altered: the natural curvatures of the long bones, for example, are increased; the direction of the processes and parts of others is changed, the most remarkable example of which occurs in the neck of the thigh-bone; and their powers of affording support and resisting violence are obviously enfeebled. This senile fragility has been generally supposed to arise from an increase in the earthy material of the bones. The opinion, however, has not been invariably borne out by the results of chemical analysis of bones at different periods of life, and has been objected to by M. Ribes,* who, after extensive observation and enquiry, was led to believe "that the fragility of bones depended essentially on a change of action being established within them, and that all the parts entering into the texture of bones are really in less quantity in the aged than in younger individuals." If by "a change of action" in the above passage is meant that gradual decrease of the vital properties observed in every organ and in every tissue as man declines into the vale of years, we cordially agree in the opinion; being satisfied that the results of chemical or mechanical enquiries, however true in themselves, will always be insufficient to explain the operations carried on within a living body.

Having offered these preliminary remarks, we proceed with an attempt at an arrangement of the pathology of the osseous system, fully aware, indeed, that every classification of disease must be more or less artificial, and, therefore, open to objection. Perhaps it may be advantageously considered under the three following heads. 1. Cases in which there is a real or supposed derangement or imperfection in the processes carried on within the bone itself in order to its maintenance in the normal or healthy condition. 2. Cases in which there is inflammation of the bone, whether produced by injury, appearing idiopathically, or connected with some specific taint. The pathological conditions of the periosteum are so intimately connected with this part of the subject, that some reference to its diseases must of necessity be made. 3. Cases in which there is alteration of the original structure or development of a new one; as thus:—

DISEASES OF THE OSSEOUS SYSTEM.

Class I. *Derangements of internal functions.*

a. Deficiency of the calcareous deposit ...... Rachitis.
b. Superabundance of the calcareous deposit .. Fragility.
c. Absorption of the calcareous deposit ...... Mollities.
d. Absorption of both constituents .... Atrophy.

Class II. *Inflammation.*

a. Simple inflammation .. Adhesion .... Union of fracture.
Suppuration .... Abscess in bone.
Ulceration .... Caries.
Mortification .... Exfoliation.
Death with regeneration .... Necrosis.
b. Specific inflammation .. Scrofula .... Absorption of cancelli.
Deposit of a cheesy substance.
Softening of the bone.
Abscess.
Caries.
Syphilis .... Deposit of fluid between the periosteum and bone. Node.
Caries.

Class III. *Structural diseases.*

a. Spina ventosa .... Development of a new cavity within a bone, with unnatural contents.
b. Exostosis .... Growth of a tumour in or from a bone, which may consist of .... Bone.
Cartilage.
Both structures mixed.
c. Osteo-sarcoma .... Alteration of structure with deposit of a new material.
d. Cancer.†
e. Fungus hæmatodes.†
f. Bloody cellulated tumour within bone.

* We refer our readers for a summary of M. Ribes' opinions, &c. to the Dictionnaire des Sciences Médicales, vol. xxxviii. p. 456 et seq.

† These diseases are generally, if not always, propagated from adjacent parts or structures.

Rickets.—The consideration of this subject has been too frequently mixed up with that of the disease entitled mollities ossium *(osteomalaxie)*, or with that of the interstitial absorption of bone which occurs in aged persons. Rachitis seems not to be so much a softening of bone that had previously been solid and perfect, as an interruption in the first instance of the process of ossification. It is a disease of early life, generally commencing, or at least first observed about the period when the infant should make its earliest attempts to walk, and rarely appearing after the age of two years. It would appear that the disease should be considered as connected with inadequate nutrition throughout the body generally, rather than as being confined to the osseous system; its effects are only most obviously marked on that system; and it is quite certain that all the bones of the skeleton are more or less affected, although particular local causes commonly produce much greater deformity in one than in another.

The early symptoms of rickets are invariably those of imperfect or deranged nutrition, paleness of skin, flaccidity of fibre, &c. Along with these symptoms or shortly succeeding to them the deformities appear which cause the disease to be ranked amongst the affections of the osseous system. In mild cases these extend no farther than to an increase in the curvature of some of the long bones and an augmented expansion of their extremities. Whether from its supporting the whole weight of the body or from the action of the strong muscles behind it, the tibia generally suffers in a remarkable degree: the legs are not only bent forwards, the curve being sharp and sudden about the lower third of the bone, but they are twisted in such a manner as to bring the internal ankle below its proper level, deformities which, notwithstanding a perfect recovery, are never completely removed afterwards. Rickets, considered alone, is not very dangerous to life: in most instances it proceeds no farther than has been already described—the visceral derangements are either subdued or subside spontaneously, the healthy functions are re-established, and amongst them that of ossification, and the patient soon becomes enabled to perform the ordinary motions, while the deformity in some slight degree disappears. But if the disease is severe or protracted, or complicated with a scrofulous taint, it generally leaves tokens behind it which embitter the patient's future existence, or hurry him to a premature grave. Sometimes the head becomes flattened, or pushed so as to project backwards, or is otherwise strangely deformed. More frequently still the chest suffers in shape, either in the ribs, the spine, or in both, and the compressed and contracted thorax, or laterally curved spine, with all their accompaniments and consequences of deranged respiration, will be the result. But of all the parts which suffer from this disease, perhaps the pelvis is that which is most frequently engaged. Placed between the spine and the thighs, it is the fulcrum and centre on which numerous motions are performed; it is surrounded by powerful muscles and subjected to irregular and unequal pressure; and it also sustains the weight of the principal part of the body. Hence arise the strangest and sometimes the most complicated distortions, and woe to the female who at the age of womanhood becomes pregnant under such circumstances. The remote consequences of rickets may, therefore, be far more formidable than the immediate.

The actual condition of a bone with reference to its structure is the next point to which we must direct our attention. Is there an absolute deficiency in the quantity of ossific matter secreted, the place of which is supplied (especially about the epiphyses of the bones) by a soft substance which increases their bulk? or is the earthy material removed by absorption previous to the deposition of this softer substance? The question is not easily answered, for patients seldom die of rickets alone; and when they perish, it is generally in consequence of some complication of scrofula producing hydrocephalus, tabes mesenterica, glandular abscesses, or, it may be, caries; and it is evident that the examination of a case so mixed cannot afford a satisfactory demonstration of the disease itself. It cannot, therefore, be a matter of surprise if some difference of opinion has existed. The following is the description of a ricketty bone as given by Boyer.* It is lighter, of a red or brown colour, pierced by a great number of dilated bloodvessels, porous and spongy, soft and compressible, moistened with a sort of sanies that may be pressed out as from a sponge, or rather from leather that has been soaked to maceration. The walls of the medullary cylinder of the long bones of the extremities are greatly thinned, whilst the bones of the skull are increased in thickness and become spongy, and, as it were, reticulated. Both the one and the other, but especially the long bones, have acquired a remarkable suppleness, but when bent beyond a certain point they break: and the fracture takes place more easily if the inflexion is made rapidly. The medullary cavity of the long bones contains, instead of marrow, a reddish serosity, totally devoid of that fat and oily character which appertains to marrow in its natural state. The result of Mr. Stanley's† experience is that the consistence of a ricketty bone is but slightly different from that of common cartilage, an opinion more consonant with our notions of the disease than Boyer's exaggerated description is calculated to convey. We ourselves have never met with that extreme degree of softness which has been occasionally described, or which would permit of the bone being divided by a knife. Meckel‡ states that the bones of ricketty patients are soft, spongy, flexible, and curved, both in situations where they are subjected to muscular actions, and where they have some weight to support. In the meantime

* Boyer, Traité des Maladies Chirurgicales, tom. iii. p. 625.

† Medico-Chirurgical Transactions, vol. vii.

‡ Meckel, Manuel d'Anatomie, tom. i. p. 344.

they receive more blood. The periosteum has undergone analogous changes. The chemical composition is not the same throughout. Thus, on the one hand, there is not always the same relation between the respective proportions of phosphoric acid and lime—sometimes too much, sometimes too little of the acid: on the other, the proportion between the animal and earthy substance varies considerably. Sometimes the quantity of animal matter is greatly increased, so that the relation is 74 : 26, or even 75,8 : 24,2, or so far as 79,54 : 20,6. Often it is the same as that met with in the healthy condition, or it is even less, as 25,5 : 74,5,* although the bones are spongy. These differences depend probably on the intensity, and, more particularly, on the period of the disease; but they prove, at least, that the essence of rickets does not consist in an original deficiency of earthy material.

It is unnecessary to quote any farther authorities to shew that no universality of opinion prevails as to the pathology of this important disease, and that it still requires careful and accurate investigation. It seems, however, to be agreed on, that when the patient begins to recover, a great activity may be observed in the deposition of the earthy material, and that it is principally deposited where it is most wanted, viz. on the concave surfaces of the curves.

Fragilitas.—We have classed a brittle condition of the bones under the head of a disproportionate abundance of the earthy substance, rather in compliance with a doctrine that was once universally believed, and perhaps is still pretty generally admitted, than as the statement of a fact that may be supported by evidence. It was supposed that the presence of a greater quantity of phosphate of lime rendered the bone short-grained and dry, and therefore more liable to snap across; and this condition of bone, as peculiarly appertaining to old age, has been placed by Boyer among the predisposing causes of fracture.† The opinions of Ribes on this subject, and the doubt cast by chemical analysis on the ordinary explanations of a softened condition of bone on the one hand, and of its fragility on the other, have been already noticed, and, notwithstanding some attention to the subject, we are obliged to leave it without even attempting a solution of the difficulty; the results even of several series of experiments, which were instituted in the years 1831 and 1832, with a view to the elucidation of this difficult question, scarcely deserve to be stated, as they were in every respect unsatisfactory. We compared the respective thickness of the thigh-bone in the adult and the aged, the section being made exactly in the middle: we weighed equal lengths of similar bones—we softened equal lengths and equal weights by means of dilute muriatic acid—and we burned equal portions and weights also, with a view of comparing them under these different circumstances, but could never arrive at any fixed or certain conclusions. In one remarkable instance the bone of a woman, who must have been seventy or eighty years of age, was thicker, stronger, and contained more both of the animal and earthy materials than any adult bone with which it was compared. We were, therefore, obliged to adopt M. Ribes' theory of " a change of action," just as we see the muscle of an old man incompetent to such a display of strength as would be easy to that of a younger person, although the latter may be smaller, and possessed apparently of less toughness of fibre.

Fragility seems to exist under two different conditions, one derived from, or having relation to, some defect or imperfection in the bone itself; the other being rather a symptom of some other disease than a disease itself, and arising from some vice or taint in the constitution. The former of these is exhibited in the fragility occasionally observed in the bones of some young persons, and more constantly in those of the old; but it may be remarked that the causes that produce this fragility (whatever they are) do not interfere with the restorative powers of the part. True, a fractured bone is tedious in uniting, and is frequently followed by unpleasant consequences in aged persons, but in such all the vital powers exhibit evidence of sluggishness and debility; whilst in youth, so far from fragility interfering with the process of union, fractured bones have been observed to be consolidated in even less than the usual period. But when any particular condition of constitution or any disease seems to be the exciting cause of fragility, it may also be regarded as a cause of subsequent non-union. Of these, cancer, fungus hæmatodes, and sea-scurvy, seem to furnish the most numerous and best authenticated instances; syphilis has been added, probably from the fact of some fractures remaining disunited until the patients had been subjected to a course of mercury; its influence, however, is questionable, unless where it had previously produced caries. A state of pregnancy or of lactation has been mentioned as predisposing to fracture, and impeding or delaying the process of re-union; but however the observation might have been occasioned by a few solitary cases, it is not borne out by general experience.

In the fragility of early youth, and where union would take place quickly and kindly, it is not to be expected that the bone (if there was an opportunity of examining it) should present any morbid appearances unless the evidences of its physical weakness in the smallness of its diameter and the thinness of its walls should be so considered. In the aged, as all persons are not afflicted with this fragility, so are there some whose bones cannot be distinguished from those of the healthy adult. As to the ordinary characters of the bones of old persons, Mr. Wilson remarks they are never found so friable and fragile as to crumble like a calcined bone, but, on the contrary, they contain a large quantity of oil; and when dried after death, they are so greasy as to be unfit to be preserved as preparations. Their

* These chemical results are quoted by Meckel from Monro's Outlines of Anatomy.

† Traité des Maladies Chirurgicales, tom. iii. p. 22.

organized vascular part is diminished, but their oily animal matter is increased.

Mollities ossium is a disease, the phenomena of which are directly the reverse of those we have just considered. In fragilitas the bone snaps across from the most trifling causes: in mollities it is flexible, bends in every direction, and, of course, is useless for the purposes of support or motion. The morbid condition seems to arise from a want of accordance between the secreting and absorbing vessels of the bones affected: if the earthy material is not secreted at all or in insufficient quantity, or if it is absorbed too rapidly, mollities will be the consequence, and we may presume that there will be variety in the rate of its progress and in the intensity of its symptoms, according to the degree of derangement of function existing at different times. It may thus be easily comprehended how fragility of bone may be an early symptom of mollities, at a period when the earthy material has been removed to an extent which renders the bone completely flexible.

Of the causes that produce this curious disease, or of the change of structure that occurs at an early period, nothing is certainly known, indeed, it is so rare an affection that little opportunity for anatomical or chemical examination in any of its stages has occurred. Boyer seems to regret our deficiency in this branch of pathological knowledge, and doubts that there are a sufficient number of authentic cases to establish such a difference between the fragility and the softness of bone as to authorize them being considered distinct diseases. There can be no doubt that in the cases of cancer, &c. which have occasioned, or been attended by, a softening of the bones, the symptom of fragility has been observed at one period or another, and perhaps there is no such thing as a softening of the bones independent of some malignant taint in the constitution. "There is scarcely any case," observes the author just quoted, "of a pure and simple softening (ramollissement) of the bones:" not one (we believe) in which they have been found merely deprived of their earthy constituent, leaving the animal material healthy and unaltered, like a bone that had been prepared by maceration in muriatic acid; whilst all the dissections of mollities exhibit such decided alterations of structure as to justify an opinion of the existence of some malignant disposition in the entire system. This view of the case ought to remove the disease from the position it holds in our classification, and place it among the derangements of structure, only that there is some reason for supposing that the first and early stages may be accompanied with the absorption of the phosphate of lime, and it must therefore signify little where we place an affection, of the nature of which we are confessedly so ignorant.

There is, however, a softness and pliability of bone (we use the word softness in opposition to softening) in which there is no malignant tendency whatever. It is original and congenital, that is, from birth the process of ossification is suspended in some part or limb. We have seen two instances of this: the most remarkable occurred in a poor man forty years of age, whose right arm was perfectly flexible, and of course powerless. He stated that he had been so from birth, but in every other respect had enjoyed the very best health; he earned his livelihood with the other arm, with which he had become wonderfully dextrous. On the nature of the cause that could suspend a particular process of nutrition in one limb, the remainder of the body being perfectly healthy, it would be useless to speculate at present.

The most extraordinary instance of mollities ossium on record is that of Madame Supiot. It may be found at length detailed by Bromfield, to whom it was communicated by M. Supe, surgeon to the hospital of La Charité.* This woman appears to have been an invalid for fifteen years, during the first five of which she suffered from great weakness in her loins and lower extremities, accompanied by great pain, which, however, did not prevent her giving birth to two children within the time. When M. Supe saw her, "the trunk was extremely shortened, and did not exceed twenty-three inches in length. The thorax was exceedingly ill-formed, and the bones of the upper extremity were greatly distorted; those of the lower were very much bent; and the thigh-bones became so extremely pliable as to permit the legs to be turned upwards, insomuch that her feet lay on each side of her head. The softness of her bones daily increased to the hour of her death." It is unnecessary to dwell on the symptoms under which she laboured, as it must be obvious that no one viscus could perform its function properly in such an extraordinary mass of deformity as she eventually became. On dissection, M. Supe says, "the bones, one may truly say, had arrived at the utmost degree of softness, as we have not heard of any observations similar to this case. In effect we have, now and then, remarked that bones become membranous and of the consistence of flesh, but I believe there never was before seen an instance of the osseous particles in the great bones of the extremities being so totally dissolved, leaving no more than the form of a cylinder by the periosteum remaining unhurt."

Mr. Gooch† relates a case which lasted five years, and which at an early period exhibited the symptoms of fragility, the patient having broken her leg as she was walking from the bed to her chair and heard the bones snap. The winter after breaking her leg, she had symptoms of scurvy, and bled much at the gums, and throughout her illness her legs and thighs were œdematous, and subject to excoriate, discharging a thin yellow ichor. From the commencement of the attack the bones continued to grow softer, and a year before her death "she breathed with difficulty, and the thorax appeared so much straitened as necessarily to

* Bromfield's Surgery, vol. iii. p. 30.

† The Chirurgical Works of Benjamin Gooch, vol. ii. p. 393.

impede the expansion of the lungs: her spine was much distorted, and any motion of the vertebræ of the loins excited extreme pain: her legs and thighs being quite useless, she was confined to her bed in a sitting posture: the bones she rested upon, having lost their solidity, were much spread, and the ends of her fingers and thumbs, by frequent efforts to raise herself, were become very broad, with a curvature of their phalanges: she now measured but four feet, though before this disease she was five feet and a half high and well shaped." After death she was found wanting in her natural stature two feet and two inches.

"All her bones except her teeth were more or less affected, and scarcely any would resist the knife: those of the head, thorax, spine, and pelvis were nearly of the same degree of softness; those of the lower extremities were much more dissolved than those of the upper or of any other part; they were changed into a kind of parenchymatous substance like soft dark-coloured liver without the least offensive smell. I cut through the whole length without turning the edge of the knife, and found less resistance than firm muscular flesh would have made, meeting only here and there with bony laminæ, thin as an egg-shell.

"Those bones were most dissolved which in their natural state are most compact, and contain most marrow in their cavities. This circumstance may appear more worthy of observation as it held throughout, and looks as if the wonderful change they had undergone was occasioned by the marrow having acquired a dissolving quality; for it was evident the dissolution began internally by the bony laminæ remaining here and there on the outside and no where else, and the pain in the beginning of the disease not being increased by external pressure."

Mr. Wilson* met with three cases, of one of which he gives the dissection, which in some respects resembles the preceding. As it exhibited the symptom of fragility,—indeed the symptoms throughout were rather such as should appertain to fragilitas than mollities, for most of the bones of the skeleton had given way, some of which were imperfectly united, and many not at all,—as the bones were altered into a substance not very unlike that described by Gooch, and as the disease evidently commenced within, we subjoin an extract from the dissection, which will be sufficient without entering into the more minute details.

"All the bones were diseased. The ossa brachiorum were so soft that I very readily divided them with a common scalpel from their heads until near the condyles. Immediately at the condyles both bones were hard, and the articulating cartilages had a natural healthy appearance; both bones had been fractured; in one the fracture had not united, and in the other there were several fractures which had united very imperfectly. The compact substance of the bone was in some places not thicker than an egg-shell: the cancelli were totally destroyed, and the cavities in the middle of the bones were filled up with a substance which seemed to have been originally extravasated and coagulated blood, but which had become vascular, and had much oil deposited in the cells within it. These substances appeared to have produced absorption of part of the bone from their enlargement and internal pressure, for in some places the external surface of the bone was removed and tumours allowed to extend through the openings."

In confirmation of the opinion that this disease is produced by some malignant taint in the constitution, it may be proper to add that hitherto it has baffled every mode of treatment. It continues its progress without stop or interruption, and is inevitably fatal.

Inflammation—osteitis.—The exact process that is carried on within an inflamed part* seems not to be satisfactorily understood, although the subject has exercised the ingenuity and employed the research of many who have distinguished themselves in the cultivation of pathological science. If this position is true with regard to the softer and more external structures which are open to examination both by the touch and eye, it must be still more so with reference to the osseous system, the parts of which are more or less deep-seated and concealed from observation. We know, however, that the process of inflammation is greatly modified by the structure of the part affected, or perhaps more particularly by its vascular organization, some powerfully resisting the inroads of disease, and repairing its ravages with wonderful activity, while others exhibit as remarkable a want of energy, seem scarcely capable of a struggle, and run at once into mortification. But as the bones, besides their animal ingredients, contain an earthy material which must exert considerable influence on the phenomena, the progress, and the results of inflammation, it will be necessary to examine the subject with reference to the nature of the structure particularly affected.

A bone in its healthy condition is copiously supplied with bloodvessels.† When examined on its external surface stripped of its periosteum, it exhibits a bluish-grey colour, evidently produced by a quantity of blood contained within it. When it is cut, or when the periosteum is torn from it, a number of bloody specks are seen; and the cancellated structure in which the marrow is lodged is always red, particularly in young subjects. By Mr. Howship's observations it appears that "the small space occupied by the bloodvessels of the canals (within the bones) compared with that which is found to be allotted to the secretions and membranes of these cavities, distinctly proves that the circulation must, under all circumstances, enjoy as much freedom here as elsewhere; and the intimate connexion formed by these canals between all parts of the bones

* Wilson's Lectures on the Bones and Joints, p. 253.

* Generally spoken of as the proximate cause of inflammation.

† See Howship's Papers in the Medico-Chirurgical Transactions.

and the surrounding soft parts affords the strongest grounds for believing that the minute vascular and membranous organization of the bones is as susceptible of impressions from irritation or sympathy as the muscular, glandular, or other soft structures of the body." The bones in common with other parts are consequently subject to inflammation with all its consequences of adhesion, suppuration, granulation, ulceration, &c. &c., but subject to the following modifications which result from the peculiarities of structure and material composition indicated, and the intimate connexion just alluded to between them and the adjacent soft parts.

1. The connexion between the bone and periosteum is so complete that it is not easy to conceive how inflammation of a bone can occur without its membranes being more or less engaged, and therefore it is difficult to meet with a case of diseased bone unaccompanied by periostitis.

2. The effects of inflammation on the membrane and on the bone must be different. One structure can swell, the other in the first instance cannot; and hence the vessels of the bone itself in a state of debility and compressed by an unyielding substance are very liable to die, whilst those of the periosteum tumefy and exhibit a more mitigated form of disease. Thus the periosteum in inflammation is generally found swollen or thickened, and detached from the bone underneath, which is then usually either carious or necrosed.

3. Those bones or parts of bones which are hardest and firmest usually die soonest, whence Mr. Wilson's remark that "they are the soonest cured," the process of exfoliation being set up by the surrounding living parts in order to remove that which is dead.

4. In the various processes of repair and reproduction the periosteum largely participates, and if this latter membrane has been injured or torn off, the vessels of the adjacent cellular tissue seem to assume a new function in order to supply its place. Thus, if a portion of the scalp is torn down, leaving the cranium perfectly denuded, it by no means follows that the bone must exfoliate if the flap has been carefully laid down and still preserves its vitality; but perhaps the best illustration may be drawn from some cases of necrosis succeeding to injuries by which the periosteum had been removed, in which the process of regeneration is commenced and completed notwithstanding.

Thus far, then, we have seen that there is little difference between the inflammatory process in bone and in any other structure of similar or equal vascular organization; the chief or characteristic peculiarities must therefore depend on the presence of the earthy material, which we shall find influencing the phenomena of the disease, but perhaps more especially its progress. Thus, whether the operation is sanative or otherwise—whether adhesion is to be accomplished, ulceration or granulation is to be set up, or a spoiled or dead portion of bone is to be removed—the progress of the work is more sluggish, and its ultimate accomplishment deferred to a much later period, than in any other animal structure. When a bone is wounded, coagulating lymph is thrown out as quickly and with as much facility as from any other tissue, but nothing can be more familiarly known than that it will require a length of time before consolidation is effected, and the solution of continuity is repaired.

The process of ulcerative absorption in any structure is scarcely understood either as to the stimulus which first determines the vessels to this action or their modus operandi subsequently; still less can we comprehend how a solid unorganized material like the earthy phosphate of bone comes to be thus removed. That this process is not performed with the same facility as in softer structures of equal or inferior vascularity is obvious from the tediousness of its progress, a delay that is therefore attributable to the presence of this earthy substance. The absorption of the earthy particles takes place under two different conditions; one without the secretion of purulent matter (dry caries), examples of which may be seen in the caries of bones compressed by aneurismal tumours, and in some cases of angular curvature of the spine. It is of importance to remark this kind of caries, and to observe that its progress is equally or perhaps more rapid than that in which purulent matter is secreted. Many writers have assumed that pus possessed a solvent quality, and by thus preparing the ossific matter for absorption, materially assisted in the process—an idea which the preceding observation strongly militates against. In the other there is a secretion of purulent matter, and the case is analogous to suppuration and ulceration in the softer tissues, except that the process is still very slow, and in general the odour of the matter is very offensive.

*Adhesion.** *Formation of callus.*—The phenomena attendant on this process are most easily and familiarly observed in the re-union of fractures. It is very remarkable, however, that considering the number of celebrated men who have directed their attention to this subject, and the opportunities for observation that are so constantly occurring, nothing has yet been positively determined. We have theories in abundance, apparently founded on and supported by experiment, but still so contradictory that it is impossible not to entertain a suspicion that the theories were in general formed in the first instance, and the facts, if they did not immediately apply, wrested a little in order to support them afterwards. Hence this part of our pathological studies consists of little more than a history of opinions and doctrines necessary to be known as constituting part of the literature of the profession, but totally unavailable to any practical purpose.

The most ancient explanation of the process by which callus is formed, is, that it was perfected by means of a viscous fluid poured out, around and between the fragments of a divided bone, which were thus mechanically glued to-

* The adhesive ossific inflammation of Hunter.

gether. This fluid, which was termed the osseous juice, was supposed to acquire the requisite consistence afterwards, and thus became the medium of a firm union. Nothing, however, was said of the time or manner in which the consolidation was effected, nor of the absorption of the superabundant part of this fluid subsequently.

The first who doubted this theory of the osseous juice, or rather who thought it insufficient, was Duhamel, a man of extraordinary ingenuity, but unfortunately not a physician, and therefore not qualified to examine or to explain the results of vital actions. He adopted his ideas as to the formation and growth of bone analogically from trees and vegetables, and supposing the periosteum to answer the same purpose to bone that the bark did to the wood, he conceived that ossification went forward by the conversion of the internal layer of periosteum into bone. It was natural, having formed this theory as to the original conformation, to advance it still farther into an explanation of the mode of re-union in fracture. He said that the extremities of the torn periosteum covering the fragments swelled; that they met, and uniting, formed a kind of brace or ferule inside and outside of the fracture; sometimes, in case of the external membrane being torn off, the internal answered every purpose alone; sometimes the external periosteum was sufficient, but in every case it was this that perfected the operation. It is needless now to canvass a theory that has long since been given up as untenable, yet as if to show how little of novelty can be expected in physiological reasoning, it will be found that an opinion not very far removed from this in its bearings was the one entertained by Dupuytren, so recently lost to science.

The next opinion to be noticed is that of Haller. This great physiologist, who was a cotemporary of Duhamel,* quite dissatisfied with the ideas entertained in his time on this subject, endeavoured to develope the truth by experiments, and conducted many, in conjunction with a pupil of his named Dethlef. The result was, that the process of re-union appeared to him to be the same as that of the original ossification; 1st, that a gelatinous or gluey substance is poured out around the ends of the fragments; 2d, that this substance becomes converted into genuine cartilage; and lastly, that an osseous deposit is laid down in the cartilage, forms a ring of bone, and gradually increases until the entire ossification is completed. This theory is principally objectionable in the regularity with which these changes are said to take place, whereas it is more than questionable whether this gelatinous fluid, the origin of the callus, ever becomes cartilage at all. Doubtless it is altered in consistence and becomes hard and firm, opaque and elastic, and thus far resembles cartilage in its sensible qualities;† but it is tinged of a red colour by feeding the animal with madder, which is not the case with cartilage; and chemical analysis shews its nature to be osseous and not cartilaginous. However, the experiments of Haller and Dethlef are entitled to great attention from the care with which they were conducted, and with a little modification their results are probably not very remote from truth.

Hunter, so happy in the doctrine of adhesion, endeavoured to extend it as widely as possible, and has certainly simplified both our notions with respect to divided parts and our practice in procuring union, although his correctness in considering effused blood to be the medium of that union has been frequently doubted. According to him, the first effect of fracture is, the effusion of blood from the ruptured vessels of the bone and the adjacent structures: this blood becomes organised by vessels shooting into it; whilst in the mean time the ends of the fragments inflame, and this inflammation produces adhesion in the surfaces that are even, and a disposition in the scales or points of the broken edges that remain, to be removed by absorption. Pretty nearly the same are the conclusions to which Mr. Howship arrived after a series of experiments conducted with great accuracy and minuteness. This paper is in the ninth volume of the Medico-Chirurgical Transactions, in which these experiments (performed on the fractured bones of rabbits) are detailed and illustrated with engravings. They refer to the appearances observed on the third day, on the fifth, the ninth, the fifteenth, the twenty-third, and thirty-second days after the fracture. The relation of these experiments singly would occupy more space than can be appropriated to this part of the subject, and we must therefore confine ourselves to the conclusions as drawn from them by the author himself. He concludes that the first effect of fracture is extravasation of blood into the surrounding cellular structures, principally that of the periosteum; into the medullary cavities of both fragments and between their fractured extremities. This blood soon coagulates; after some further time its colouring matter disappears; and the thickened periosteum becoming more firm assumes the sensible characters of cartilage. The deposition of osseous matter takes place within the coagulum, beginning at the part nearest the fracture and extending gradually from this point: it even commences in the clot situated within the medullary cavity before the colouring matter is removed; but under every circumstance and in every situation, we are to understand that the coagulum of blood is the nidus of ossification and the medium of union between the fragments. Notwithstanding the respect due to such high authority, there are many who do not believe in the possibility of effused blood becoming organised, and look with doubt and suspicion on every experiment and every observation by which such a doctrine is sought to be established. They reason, that if, under any circumstances, blood became the medium of union, we ought to leave the

* Haller was born a short time after Duhamel, and died before him, this latter philosopher having attained the age of 82.

† Macdonald.

surface of a stump or other wound covered with clotted blood, and spare ourselves all the labour and pains we employ in removing it and placing the cut surfaces cleanly in apposition with each other. And they also remark that when a clot of blood is left behind, how very commonly, instead of becoming organised, it lies as a dead substance in the wound, impedes the union, promotes suppuration, and imparts to the discharge a putrid and offensive odour. These pathologists suppose that in many instances the fibrine of the blood has been mistaken for coagulating lymph, which is the natural product of the vessels in the adhesive stage of inflammation, is capable of becoming organised, and ought to be the legitimate seat of any deposit to be afterwards laid down in completing the process of union.

We now pass to the theory of Bordenave, Bichat, and Richerand, who make the union of fractures analogous to that of the soft parts by the *second intention*, or by means of granulation. Like other pathologists, they have supported their opinions by observation and experiment; and without entering into the minuter circumstances connected with this hypothesis, it will be necessary to mention some very familiar facts that bear upon the case. In necrosis, the surface of the new or growing bone is *often* seen covered with granulations. In cases of amputation, when the bone protrudes after eight or ten days, the cut extremity is observed to be fungoid and granulated. And in *some cases* of compound fracture we can observe the process of granulation going forward, and actually see that it is thus the union is completed. It nevertheless appears very doubtful whether granulation has any part in the process of uniting a fracture, unless where a communication exists between the broken ends of the fragments and the external air. In a compound fracture, or in the case of a bone protruding from a stump, there will be granulations, often to a degree of excessive exuberance; and in them there will be a deposit of osseous substance, because new structures always assume to a certain extent the nature of the parts from which they are produced; but in a case of simple fracture, where there is no wound, no communication with the atmosphere, and not a single drop of purulent matter is formed, it is very doubtful whether granulations could exist; at least their existence has never been demonstrated.

Amongst modern pathologists, Meckel's* opinion is entitled to very great respect, although we may not be disposed to accede implicitly to his views. He ranks among those who consider the process of consolidation in fracture to be similar to that of original ossification, and states, that at first there is an effusion of a gelatinous substance which gradually becomes firmer and more solid in consistence, and is converted into cartilage, in the interior of which osseous nuclei appear that join to each other and to the broken ends of the bone, and also envelope any fragments that may have been detached. At the same time the spiculæ or scales become rounded off in order that the surrounding parts may not suffer injury or irritation. It is not necessary to the perfection of this union that the ends of the fragments should be accurately in contact: it is sufficient if they lie against each other, and then the union occurs by the same means, and exactly on the principle of anchylosis taking place between different bones. It must be understood that this ossific deposit is laid down both external to and within the bone; that when union is complete, the bone is divided into two cavities internally; and that, for a length of time afterwards or for ever, it may be known, by making a longitudinal section, whether a bone had ever been broken or not. He further states that the part surrounded and joined by ossified callus is stronger and firmer than any other, and to all appearance this observation is correct, but it is contrary to one of Mr. Howship's experiments, who saw the callus break down and crumble away in an attempt to calcine it, and therefore concluded that it was softer and more highly animalized.

Hitherto we have noticed a number of theories, all of which, with the exception of that of Duhamel, bear a strong similarity to each other, the principal points of difference being, 1. as to whether the soft gelatinous substance, which all agree in having seen, was the fibrine of the blood deprived of its colouring matter, or genuine coagulating lymph effused by inflamed vessels: 2. whether this in process of time was changed into real cartilage, or the osseous deposition took place into this lymph very much inspissated: and, 3. whether anything like adhesion happened, or the consolidation was perfected after the manner of union by the second intention, namely, by granulation. We now proceed to take a view of a new theory bearing some resemblance to that of Duhamel, and supported by the authority of Dupuytren. He supposes that there are two distinct and different processes in the union of bone. First, that there is a callus formed like a brace or ferule round the fragments externally, with a plug of the same material within, the object of this provision being, to hold the ends of the fracture in apposition whilst the union that is to be permanent is going forward: thus we are to imagine a kind of natural splint placed around and within the fractured pieces in order to preserve them in situ. This preliminary process commences almost immediately after the accident, and is completed in the space of from four to six weeks. Matters remain thus, while the ends of the bones are becoming permanently united, which they are in about eight months, during the latter period of which time the mass of new material is declining in size, and is eventually removed so as to leave the bone of its natural extent and figure. The formation of this first callus, which he calls "cal provisoire," is attributed to the periosteum and occasionally to all the surrounding structures, and in the centre of it he sup-

* Manuel d'Anatomie, tom. i. p. 335.

poses the fracture to remain for a considerable time un-united, the limb being, of course, weaker here, so that, in the event of the occurrence of a new fracture, this will be the spot in which it will give way. The second or permanent callus, which he calls "cal definitif," is the actual medium of union between the fragments, and remains like the cicatrix of a wound in the soft parts.

It must appear curious to the reader that no positive conclusion should have been obtained on a point which has occasioned so much inquiry, and which apparently was so easy of determination. It is open to experiment; obvious to the senses; and there are few sources of fallacy except such as might arise from previously adopted views of the experimentalist, and perhaps from different periods puring the progress of ossification being chosen for making the observations, and the same thing, of course, being seen under different circumstances. We think it might have been reasonably suspected from analogy, (and the experiments of Breschet and Villermé have confirmed the idea,) that nature, in the simplicity of her operations, produced every where similar effects from similar causes, and that, in whatever manner the re-union of divided soft parts was accomplished, the same would hold good as to bone, only allowing a longer time in order to admit of the consolidation of the lymph by osseous deposition. And such is probably the fact. In an incredibly short space of time after the receipt of a fracture, the process of repair seems to be actively commenced: coagulating lymph is effused in considerable quantity, probably mixed with blood, as the coagulum is found to possess a more than ordinary firmness and consistence. At the end of the second day the torn edges of the periosteum are evidently thickened, pulpy, and vascular, easily receiving coloured injections. At the end of the fourth day, we have seen the sharp edge of the fracture beginning to be rounded off. Where the surfaces of the fragments are broad and thick, it is easy to observe them coated with a deep layer of lymph, which adheres to them tenaciously from a very early period. If the fragments are in apposition, the torn extremities of the periosteum are united by the intervention of this lymph, the membrane appears greatly thickened also, and seems to afford a kind of protection to the fracture; or, otherwise, an immense and irregular mass of lymph is thrown out around both fragments, filling up all the space that has been occasioned by the displacement of the bones and the laceration of the soft parts. In effecting this deposition, all the vessels of the part, those of the bone, periosteum, and adjacent structures, seem to be equally engaged. In process of time this ymph becomes organised, assumes a ligamentous rather than a cartilaginous appearance, although, strictly speaking, the new structure possesses not the true characters of either, and inally is converted into bone by the simultaneous establishment of numerous but irregular specks of ossification. This process varies as to the time required for its completion according to a number of circumstances, such as the situation of the bone, the part of it broken, the apposition of the fragments, rest, and many others that need not be enumerated here; as well as the age and constitution of the patient, which exert such marked influence on all cases, that it is impossible to lay down certain rules for calculating the time that may be required for the union of any given fracture.

The process of re-union, however, is sometimes very imperfectly performed; sometimes it is suspended indefinitely, and occasionally it is not performed at all. Of the causes that occasion these deviations from the natural and usual progress of ossific union we are in general ignorant, although there are many cases in which former experience may enable us to predict the occurrence of such an event. It has been already stated that the diseases which occasion a fragility of bone will be likely to interfere with its subsequent union, and in these cases little more is accomplished than the removal of the sharp spiculated edges by absorption: the presence of such a constitutional derangement as would occasion a bone to give way in the effort to turn in bed will be sufficient to explain its want of re-union. But these are not the cases generally met with. When there is an un-united fracture, or as it has been termed, a false joint, the ends of the fragments are not smooth and polished moving on each other like articulated surfaces, but are joined together by the intervention of a ligamento-cartilaginous substance, which, according to its extent, is more or less flexible, and of course incapacitates the bone from the performance of its functions of support and motion. This imperfect union occurs in some bones with wonderful regularity; we may, for instance, calculate on such an event in fractures of the neck of the thigh, and in the transverse fracture of the olecranon and patella; but it happens at other times quite unexpectedly, in cases wherein we could suspect no possible cause, in which there may have been no neglect, no impropriety of treatment, to lead to such a result. We have lately seen two cases of fractured femur remain un-united at the end of five and six months in the persons of fine and apparently healthy young men, although the ends of the bones were kept in apposition, and in every other respect the treatment was correct.

The chief causes* to which this imperfect union has been attributed are a removal, or rather a withdrawing of the broken surface of one fragment from the other, a want of vascularity in one of the fragments, and the fracture not being maintained in a state of uninterrupted repose.

The frequency of this occurrence in fractures of the above-mentioned bones, in which the fragments are always withdrawn from each other, was too remarkable not to lead to the connexion of the circumstances as cause and

* Sir A. Cooper on Dislocations and Fractures.

effect, the only objection being that the result is not uniform and universal. Fractures have been submitted to each of the above conditions, more especially to the maintenance of exact co-aptation for months, yet has no ossific union been produced; and again a firm consolidation has taken place between two bones, the extremities of which had been sawed off and the parts placed under circumstances that could not permit of the approximation of the divided surfaces. We have a case published as having occurred in the hospital of La Charité in Paris, in which the os calcis was broken; and although the surfaces of the fragments were never completely separated, yet the usual kind of ligamentous connexion took place; and for proof that a solid union may occur under the circumstances above-stated, we refer our readers to Mr. Crampton's second case of extirpation of the knee-joint.*

If we can subscribe to Larrey's opinion that only the vessels of the bone itself can minister to osseous union, and that those of the periosteum and adjacent structures are incompetent to such function, (an opinion in which he is to a certain extent supported by Mr. Liston,†) it is obvious that a union between fragments at a distance from each other would be difficult if not impossible. Here, however, as well as in every other part of the history of ossific union, it is only conjecture. We have nothing like substantial definite proof, and must only rest satisfied with a knowledge of the fact without being able to explain it, that the medium of union between fragments, the faces of which are withdrawn from each other, is in general not osseous.

Whatever may be the operation of this cause, that of the other two is by no means so obvious. The second ‡ has been generally adduced in explanation of the non-union of fractures of the neck of the thigh-bone, but perhaps without being entitled to the importance that has been attached to it. If a part is only possessed of a degree of organisation barely sufficient to preserve its vitality in ordinary circumstances, but inadequate to accomplish any process of repair, it should follow that any violence offered to it ought to cause its death, or at least its removal by the absorbents, and in such case the caries or exfoliation of a fragment of bone might be easily understood. But these are not the results of fracture of the neck of the femur except in very rare and anomalous cases; and, on the contrary, there is scarcely an example of examination after death that did not exhibit a considerable display of reparative energy, although the results were not such as to produce ossific union. Professor Colles § has published twelve cases of post-mortem examinations of this accident, in some of which he observed the appearance of ivory-like patches on the surface of the superior fragment, evidently proving the existence of considerable ossific powers in this part. Besides, this condition of the head of the bone has been assumed rather than proved. On the most attentive examination, we have not been able to observe any deficiency of vascularity within it; and if there is any difference between the head and neck and shaft, we are rather disposed to believe the head to be possessed of the highest degree of organization.

The advantage of the most absolute rest to the cure of fracture has been observed in all ages, and yet is it doubtful how far its influence on the question under consideration can be appreciated. Few fractures can be kept in a more perfect state of repose than those of the patella or of the heel, yet the union in both these cases is always ligamentous. It would appear as if constant although very trifling motion was more prejudicial than occasional shocks however rude and productive of greater disturbance, and this perhaps is the reason why false joints so frequently occur after fractures of the clavicle, even although the fragments have never suffered displacement, as occurs when the bone is broken near its acromial extremity.

Suppuration may occur in the osseous tissue under a variety of conditions, as to situation, as to the character of the matter, and as to whether it is produced by or connected with any constitutional or specific taint. Pus is occasionally, though not frequently contained in a cyst or sac within a bone, as the result of inflammation, and resembling the common abscess in the soft parts. These collections are never very large; they are usually situated in the thick and spongy parts of the bones, and have a strong tendency to burst into the neighbouring joint. We have seen a case of abscess in the head of the tibia, which appeared to have opened into the knee-joint even after it had burst externally. The disease had previously existed for months, the patient suffering very little either locally or constitutionally until the communication with the cavity of the articulation was established, when the symptoms became so aggravated as to demand the speedy removal of the limb. The symptoms of suppuration within a bone are exceedingly obscure, nor is there any certainty until the abscess has burst and a probe can be passed into the cavity, particularly if the inflammation has not been attended with enlargement of the bone. The pain is said to be agonizing, but this is not universally true, and we may infer that suppuration has taken place "by the violent symptoms of active inflammation lessening, by cold fits and shivering occurring, by a remission of pain with an increased sense of weight in the part; but all these are fallacious, and no external marks of suppuration are at first to be observed, the disease affecting parts too deep to be seen with the eye or felt with the finger."*

Suppuration on the surface of a bone is of very common occurrence, and so constantly complicated with affections of the periosteum

* Dublin Hospital Reports, vol. iv. p. 236.
† Elements of Surgery.
‡ Cooper's Surgical Essays.
§ Dublin Hospital Reports, vol. ii. p. 334.

* Wilson on the Bones and Joints.

that it is difficult to say which structure is the source of the purulent secretion; the disease, indeed, is generally described under the name of periostitis. We are disposed, however, to regard it as inflammation of the bone in the first instance, although the membrane comes very soon to be engaged; because in many cases the pain in the commencement is not aggravated by external pressure, which it uniformly is when the periosteum is engaged, and also because in very severe cases, such as paronychia periostei, a portion of the bone becomes carious, and is lost even from the earliest period. It is most frequently observed in connexion with some constitutional taint, such as scrofula or syphilis,* but it may and very often does appear purely as an idiopathic disease. "Inflammation of the periosteum, unconnected with any known constitutional disease, is an affection with which practical surgeons are well acquainted. It is remarkable, however, that a disease so important in its consequences and of such frequent occurrence, should not have been noticed in any systematic work, nor have been made the subject of any separate inquiry."†

Whether we consider this affection to belong primarily and principally to the bone or periosteum, it is certain that the former structure always is engaged, and shews the most evident marks of activity in the disease, although this, perhaps, may in part be explained by the fibrous texture of the membrane and its deficient organization. The bone is always inflamed. Even in the most chronic case that leads only to a thickened condition of the periosteum, the bone is preternaturally vascular, and so soft that it is often difficult in such cases to distinguish the limits between the softened bone and the condensed periosteum.‡ In the severer forms, the bone, unable to sustain itself under the excitement, is always dead, and must be gotten rid of by ulceration or exfoliation: in these cases the periosteum is detached, and a fluid, very generally thin, ichorous, and fetid, is interposed between them. Between these extremes there is every possible variety, and, therefore, there will be vast differences in the results of the inflammation, sometimes in the mere thickening of the periosteum, sometimes in the deposition of more bony matter, or the apparent ossification of the membrane (exostosis); occasionally in the absorption of the bone, and most frequently, particularly in specific diseases, in that which is our more immediate object, the deposition of purulent matter.

A node is a swelling situated over a bone, hard, firm, and exquisitely tender to the touch, not round or circumscribed at its base, but gradually subsiding to the level of the adjacent parts, and not discoloured on the surface. It is at all times painful (except in some scrofulous cases), and when arising from a venereal cause, is subject to nocturnal exacerbations of great severity. The morbid anatomy of the disease is not always the same even when examined at the same period of duration, being modified by a number of circumstances, such as the age of the subject and consequent vascularity of the bones; the structure of the bone engaged being solid and firm or soft and spongy; but more particularly by the fact of the disease being idiopathic, or produced by some constitutional affection. The scrofulous diseases of bones seldom or never exhibit the symptom of nodes, although attended by suppuration, because they affect their substance rather than their surfaces: idiopathic nodes, or those produced by injury, do not suppurate unless the violence used is great; on the contrary, these are cases which so frequently terminate in thickening of the periosteum, &c., and often, when cut into, scarcely afford any perceptible discharge. The venereal or mercurial node offers the best example of suppuration. At an early period, if an opportunity occurs for examination, the periosteum round the margin of the effusion shews a more than ordinary degree of vascularity; immediately covering the tumour it is somewhat paler, more opaque and thickened. The bone underneath is denuded and soon runs into caries; between it and the membrane the matter is deposited, thin in consistence, dark-coloured, and sanious.

There are other forms of suppuration on the surface of a bone of too much interest and importance to be omitted, such as those large depots which occasionally occur after severe injuries or operations, as the accompaniments of inflammation of the veins, or as the sequelæ of acute fevers. In general, the matter is in great quantity and of a good and healthy character, though sometimes it is otherwise, and particularly in that form which attacks a stump after amputation. We have seen the entire remnant of the bone up to the next articulation denuded of its periosteum, while quantities of green and fetid pus could be pressed from the very depths of the wound. In these cases the veins are generally inflamed, the divided ends of the muscles pale, flaccid, and sloughy, and the patient seldom or never recovers. Where the deposition has taken place after fever, if the patient is young and the constitution has enabled him to combat the original disease, a recovery very frequently takes place by the process of necrosis.

* Of all the causes that produce these affections of the bones, an irregular or protracted use of mercury seems to be the most efficacious. Many surgeons of the present day doubt whether a suppurating node is a true or genuine venereal symptom. We have learned from an experienced army surgeon, who spent many years on the western coast of Africa, where the venereal disease is not known, but where mercury is profusely employed in the treatment of liver complaints and other diseases incident to the climate, that affections of the bones, resembling those considered to be venereal, are of exceeding frequency. It is a remark worthy of attention to the curious in such matters, that nodes, &c. formed no part of the symptoms of syphilis as first observed and described, and that the first practitioner who noticed them (John de Vigo, 1519,) is mentioned by Astruc, (page 158,) as an eminent promoter of the mercurial method of cure, and as having by that means acquired great reputation and riches.

† See a paper by Mr. Crampton, in the Dub. Hosp. Reports, vol. i.

‡ Ibid.

Caries from a scrofulous cause, generally, if not always, commences in the cancellated structure; that from syphilis affects the firmer and more external parts of the bone. The former attacks the ends of the long bones and the spongy and cuboid bones generally; the latter, the centres of the long bones and the flat ones. Venereal nodes principally affect the bones which are nearest to the surface of the body, the skull, the tibia, or the sternum; it being rare to see the humerus or femur thus diseased, whilst they are by no means exempt from idiopathic or strumous inflammation. But the most remarkable differences to be observed between caries arising from a specific cause, and that which occurs idiopathically or from injury in a constitution otherwise good, occur in the progress and termination of the disease. The process seems to be analogous to that of ulceration in the softer tissues, and when recovery takes place, it is by granulation and cicatrization in like manner. Thus, if we suppose an abscess to occur on the surface of a bone in a healthy man, when it is opened or has burst, we find that a scale or shell has lost its vitality and must be thrown off by exfoliation, and soon exuberant and florid granulations are seen springing from below as if to force the offending substance off, and the discharge from the cavity is healthy pus. On the other hand, if a venereal node is opened on the skull, the pericranium is here detached, the table is carious and will exfoliate, but there is (as long as the taint remains) no effort at reparation; the discharge is thin, ichorous, and unhealthy; and if we may judge by the representations we see of venereal caries, (for in modern times mercury is not so unsparingly used and real specimens are not numerous,) the disease would progress until the skull was fairly corroded through. Again, the lymph secreted in scrofulous inflammation is not healthy, and there are seldom granulations; whilst the matter is either of that whey-like appearance so remarkable in such affections, or else a foul and fetid sanies. Every one conversant with surgery must know how tedious and obstinate a scrofulous caries is, and how frequently it involves the loss of limb or of life.

The true scrofulous affection of the bones occurs so frequently in this country as to require particular attention; it constitutes the vast majority of the diseases of the osseous system that we are called upon to see and to treat. It commences (as we have said) in the cellular or cancellated structure. In the first instance there is an increase of vascularity, which, though not always apparent to the eye, may easily be proved by injection. Next, there is an absorption of the natural contents of the cancelli, and in their room a substance is deposited of a yellow or white colour that has been described as resembling cheese in consistence; it is, however, most probably a species of that flocculent unorganized lymph, such as is seen coating the cysts of scrofulous abscesses. The cancelli themselves are occasionally removed, and masses or patches of this unorganized material deposited in their stead, hence the bone becomes lighter, and so soft as to allow of being cut with a knife. It is remarkable that the disease may have existed up to this period, when it is probably incurable, without much pain and without external swelling to attract attention to the mischief underneath. In the Museum of the School of Anatomy, &c. of Park-street, Dublin, there is a preparation to illustrate necrosis of the centre of the shaft of the thigh-bone, for which the limb was amputated. The patient during life never complained of the knee, neither was there the smallest enlargement of the articulation; yet after removal the condyles of the femur internally were completely softened, the external shell of solid bone being reduced in thickness nearly to that of parchment, the cancellated structure completely removed, and its place occupied by this cheesy substance.

This condition of the bones is considered by Mr. Lloyd* as constituting the first stage of scrofulous disease, and he justly remarks that it is quite uncertain how long they may continue in this state without further mischief taking place. The next step is the erosion or absorption of the cartilages, if the affection is situated in the head of a bone, (see Joint,) or otherwise near an articulation, and probably about the same period the external soft parts sympathise, and lymph is extensively deposited around the deep fibrous tissues in the neighbourhood. This lymph is afterwards to become the seat of abscesses, which always communicate with the diseased bone, and very generally with the cavity of the adjacent joint. The limb or part is now swollen: the tumefaction is round and well defined, tolerably firm in consistence, and elastic to the touch; the colour of the skin is of a more than ordinary paleness, and its surface is marked by the meandering lines of numerous small blue veins. The growth of the tumour seems to be limited, for having reached a given size it becomes stationary and never increases, although the disease may appear at times even more fully developed. Subsequently the pain is very variable; that attending on scrofulous diseases being generally described as dull and heavy rather than acute, but this idea must be received with some limitation, for occasionally the very reverse is the truth. We have seen some patients the victims of most intense irritation and suffering throughout every stage of carious ulceration; and even when it is otherwise, they are always liable to severe exacerbations on any injudicious attempt at motion, any improper diet or other irregularity. In all cases there seems to be a considerable aggravation of symptoms, both local and constitutional, about the period when suppuration is established, and whilst the matter is progressing towards the surface.

It may be a long time before the tumour gives indications of being about to burst externally, partly perhaps from the imperfect organization of the lymph by which the matter is

* See Lloyd on Scrofula.

secreted, and partly because it seldom takes the shortest route to the surface, but proceeds by devious and intricate windings. At length the tumour, at one limited and almost circumscribed spot, becomes soft, then assumes a dark red or purple colour, finally a small slough forms on the surface and it bursts, giving exit in general to a greater quantity of matter than the size of the abscess would have led us to anticipate. The abscess does not collapse, and although the discharge may continue in profusion for months, the size of the tumefaction is never proportionally diminished. After it has burst, a small papilla of very red granulation (a most unfailing symptom of the existence of a diseased bone underneath) is pushed out through the aperture. From the centre of this a small drop of matter can generally be pressed, and through it the discharge flows; never for obvious reasons profusely at a time, but still so constantly as to soil the dressings and the bed-clothes extensively in a single night. When a probe is passed down to the bottom of this ulcer, which it is not easy always to accomplish, the bone is felt completely denuded, soft and rotten, and the instrument sinks into it with very little resistance. Most frequently the earthy material of the bone is removed by the absorbents; sometimes a small portion of it thus detached is washed off by the discharge, and is occasionally found blocking up the little orifice, occasioning a good deal of irritation and pain, and almost always an access of fever. Sometimes the remains of the bone come away in a larger mass, quite dead, light, and porous, and, when dried, perfectly friable.

Previous to the formation of the matter, however, the pathological state of the bone has undergone a remarkable change. Hitherto we have seen that an increase of vascularity occurred at an early period, and preceded the deposition of the soft and cheesy substance; but in proportion as this deposit is increased in quantity, the vascularity decreases, and with it the vitality of the bone. " If a scrofulous bone be injected at an early period," says Mr. Lloyd, " or before the whole of its cancellous structure is altered, the injection very freely enters its vessels; but if it be injected at a more advanced period, there evidently appear to be fewer vessels, though it is very probable that a fine injection may be forced into vessels which had previously ceased to carry blood." In the correctness of this observation Sir B. Brodie coincides, as well as in the opinion " that this diminution of the number of vessels, and, consequently, of the supply of blood, is probably the proximate cause of those exfoliations which sometimes occur, where the disease has existed for a considerable length of time, especially in the smaller bones."*

Although carious ulceration, or, as it would be more correctly termed, absorption of bone, is so frequently attended by the formation of matter and abscess, yet such is by no means a necessary consequence—at least, we have examples of the removal of large portions of bones without any such unfortunate accompaniment. These principally appear under two distinct forms: one, where such absorption is the result of inflammatory action within the bone itself, the most familiar illustration of which is to be found in the caries of the spine attending on some cases of angular curvature: the other, where the absorption has been occasioned by the pressure of an aneurism, an abscess, or other tumour in the immediate neighbourhood.

Mr. Pott, and others who have described this caries of the spine, mention that, at first, the bodies of the vertebræ seem to spread so as absolutely to become larger than in a state of health; that the ligaments are loose and detached, and the intervertebral cartilages separated from the bone. The first part of this description is certainly not correct, for in all the subjects we have had opportunities of examining, nothing like an enlargement or swelling of the bone appeared. It must be recollected that dissections of this disease at an early period are rarely met with—never unless the patient had been accidentally seized by some mortal affection soon after the spine had been attacked. It may, therefore, be supposed that these early descriptions were taken from analogy with what other bones suffer in scrofulous disease, and it is well known that, until a comparatively recent period, it was a universally received opinion that the heads of bones became actually enlarged under similar circumstances.

Sir B. Brodie, who has given the clearest as well as the most succinct description of caries of the spine we have met with, considers that its pathological history may be arranged under three heads.

1. " It has its origin in that peculiar softened and otherwise altered condition of the bodies of the vertebræ, which seems to be connected with what is called a scrofulous state of constitution. In these cases ulceration may begin on any part of the surface, or even in the centre of the bone, but in general the first effects of it are perceptible where the intervertebral cartilage is connected with it and in the intervertebral cartilage itself."*

As this is an instance of scrofulous caries, such as has been already noticed, it should perhaps have come more legitimately under consideration in that part of our article. We prefer, however, to take a distinct and separate view of caries of the spine, because the locality invests the disease with some peculiarities. For instance, this scrofulous caries is almost invariably attended by abscess, and we find these collections to be much larger in quantity of contents, and, if possible, more sluggish in approach to the surface than when situated elsewhere. Their existence, therefore, may not only not be suspected, but the symptoms occasioned by them during life may be attributed to a totally different cause. They are least

* See Lloyd on Scrofula, p. 123, and Brodie on the Joints, last edition, p. 195.

* Brodie on the Joints, p. 243.

frequently met with in the neck, but when so situated it is easy to conceive how they may occasion dysphagia or difficult respiration. We have seen a case where such an abscess occasioned symptoms resembling those of compression of the brain, and we have the notes of one in which death was produced in a very sudden and unexpected manner, the matter having burst into the sheath of the spinal marrow. They may also occur in connexion with disease of the dorsal vertebræ, and within the chest give rise to symptoms resembling the different forms of deranged respiration—thoracic aneurism—and, under peculiar circumstances, even of empyema. Such difficulties are now not so likely to occur, as we have auscultation to assist the diagnosis; but we recollect to have seen more than one ease treated as a pulmonary affection, the real nature of which was caries of the dorsal vertebræ, complicated with abscess pressing forward within the posterior mediastinum. Abscess in the loins connected with diseased vertebræ is too familiar an occurrence to require any lengthened details.

As far as our own observation can guide us, we believe the appearance of abscess as an accompaniment of spinal disease to be almost always a fatal symptom; and when, in the course of a wasting and protracted discharge, spiculæ of earious bone, or portions of a substance resembling ivory or enamel are seen to come away, the aspect of the case is still farther formidable—very few, if any, ever recover under such circumstances.

2. " In other cases the vertebræ retain their natural texture and hardness, and the first indication of the disease is ulceration of one or more of the intervertebral cartilages, and of the surfaces of bone with which they are connected."*

" There is still another order of eases, but these are of more rare occurrence, in which the bodies of the vertebræ are affected with ehronic inflammation, of which ulceration of the intervertebral cartilages is the consequence."

We shall now proceed to detail the results of our own observations, in order to see how far they coincide with those of the learned and accurate surgeon already quoted.

In two instances we have, in the dissecting room, seen the intervertebral substance eroded at the anterior edge, the bodies of the adjacent bones remaining unaltered in shape or consistence, and to every appearance in a perfectly healthy condition. These were, at the time, regarded as specimens of the very earliest and incipient stage of the disease, and although no clue could be obtained as to the history of the eases, it is worthy of remark that not a trace of scrofulous disease could be discovered in any other parts of the bodies.

In general, however, it is otherwise. The body of the bone seems to be seized with scrofulous inflammation, and the peculiar effects of this morbid action are produced within it. It becomes softer in consistence, in consequence of the absorption of its osseous particles, and a deposition of the cheesy lymph in its stead. At this time, although so soft as to admit of being cut with a knife, the bone appears unaltered as to size or shape, but its absorbents begin to act upon the ligaments and intervertebral cartilages, and hence is it that the separation and ulceration of these are amongst the earliest appearances. In many instances the connexion between the cartilage and bone is so much impaired, that if we wanted to separate them with a knife, the former would come off in one entire flake. The edges then begin to be eroded and ulcerated, as if gnawed by a mouse; and at this period also the ligaments are often found thickened and softened, and matted up together into a confused and indistinct mass. The body of the bone then becomes carious, and the ulceration eommences at the anterior part of it: very rarely is the posterior layer of firm bone, that forms the front of the canal for the spinal marrow, affected; and never does the caries spread to the processes. Up to this period it may be, and often is, a specimen of purely dry caries, being unattended by the formation of a single drop of purulent matter.

As the disease proceeds, and the bodies of one or more vertebræ are removed, those which remain approximate more or less above and below: the spinous processes project, and a bending of the body forward is produced. The character of this curve is influenced by the extent of the destruction that has been aecomplished within; it is sharper and more angular when the body of one vertebra only has been removed; it is more sweeping and gradual when three or four have suffered. Never, we believe, is the angle so sharp as to permit the denuded surfaces of the vertebræ above and below to come into actual contact, the sound eondition of the bony parietes of the spinal sheath effectually preventing this; and hence, when recovery takes place, it is not by the adhesion of these surfaces, but by the formation of a quantity of new bone which fills up the vacant space, producing a perfect example of true anchylosis.

The developement of such a curative process as this is scarcely to be expected in a scrofulous system, yet is it satisfactory to know that even under such circumstances the ease is not utterly hopeless. We have seen repeated instances of angular curvature without the occurrence of abscess, in patients apparently deeply tainted with scrofula, one of which is so very remarkable as to deserve particular notice, because it illustrates a mode of union that frequently occurs in scrofulous cases, and because the preparation is in existence to demonstrate the fact. In July, 1830, a wretched young girl was brought into the Meath hospital with a very acute angular curvature of the dorsal vertebræ. Almost every joint in her body was diseased, and the knees so extensively that the eroded condyles of the thigh-bones were exposed, from the surface of one of which the mud of the street was wiped away after her admission. It need scarcely be added

* Brodie, loc. citat.

that her sufferings were not of long duration, and an opportunity was speedily afforded for examining the pathological condition of the back. It appeared that three of the vertebræ had been engaged, the spongy portion of one of which had been completely removed. There was nothing like a reproduction of osseous material, although the caries had long ceased, and the spine was sufficiently strong for every ordinary purpose of support; but the space that had been left by the absorption of the bone was filled up by a ligamento-cartilaginous substance, which, attached like a new and adventitious ligament to the vertebræ above and below, held them with a sufficient tightness to prevent the smallest motion, and gave to the entire column a tolerable degree of firmness. We have also seen examples of true bony anchylosis in patients apparently scrofulous, but it seems to occur generally in males rather than in females, and more particularly in patients about or approaching to the age of puberty, a period at which it is generally supposed some important change takes place in the constitution of scrofulous subjects. Where there is no such taint, or where, as Sir B. Brodie expresses it, the bones retain their natural texture and hardness, it may be easily conceived that a cure is effected in less time and with less difficulty.

There is another specimen of caries or ulceration of bone without the formation of matter, occasionally observed in the neck of the thigh-bone of very old persons, the symptoms of which have particular relation to the hip-joint; we shall therefore postpone our remarks on it until we come to discuss the pathology of joints.

Necrosis.—There are few subjects more interesting either to the pathological inquirer or to the practical surgeon than the death of a portion of the osseous system, and the circumstances connected with this event. Neither is there any one with respect to which the ideas of medical men generally are less definitively settled. Thus also some confusion has crept into our nomenclature, and *necrosis* and *exfoliation* have been often indifferently used, as if they applied to one and the same diseased action; or, perhaps, to speak more correctly, the term necrosis has been made to extend to every case in which a bone or a portion of a bone is deprived of vitality, no matter how the dead material is to be removed or replaced. According to the etymology of the term such is in fact its true meaning; nevertheless, we are hardy enough to dissent from this application of the word, and to confine its use to one form of the death of a bone, exfoliation more properly belonging to another. And we do so the more readily because not only do these two affections present different pathological phenomena, but there are such practical discrepancies between them that it is essential to every surgeon to have a distinct and separate notion of each.

Exfoliation, then, expresses the death of a portion of bone which is either never replaced, or replaced by a process which is set up *after* its death, and is analogous to mortification in the soft parts, where the slough is thrown off, and the consequent ulcer subsequently heals by granulation and cicatrization.

Necrosis is the death of a bone or part of a bone accompanied by a process of regeneration established at a time coeval or nearly coeval with the inflammation or accident that deprives it of vitality. In this point of view the disease is singular, there being nothing like or analogous to it in any affection of the soft parts.

Necrosis is rarely a disease of early and never of advanced life, being, except in cases where it attacks the lower jaw, almost exclusively confined to the period between the ages of ten and twenty-two: exfoliation may occur at any time, but is more likely to appear in the adult or the aged.

Necrosis, although it may succeed to accident, as in this manner compound fractures and other injuries are not infrequently repaired, yet is it more generally an idiopathic disease, or may be the sequela of continued fever; whilst exfoliation in the great majority of instances is the consequence of injury.

According to the acceptation in which we employ the term, it is extremely questionable whether necrosis is ever a disease of the flat bones; at least, except in the instance of the lower jaw, we have never met with an example of the death of one of these structures accompanied or even followed by a regenerative process.

As necrosis, then, presents a solitary example of the efforts of nature in counteracting, or rather in providing against the ravages of disease, the process by which it is accomplished becomes an exceedingly interesting subject of inquiry. Different opinions are entertained upon this subject. It seems to be agreed upon all sides that the commencement of the disease is marked by inflammation of the bone: at this period it is red, vascular, and receives the tinge of coloured injections. How this inflammation may be caused or why it is followed by the formation of new bone, are points not so easily determined. Troja introduced a sharp instrument through a bone, by which he contrived to destroy the internal periosteum and marrow, and thus produced a number of cases of necrosis, which presented the same symptoms and ran the same course as if they had been examples of idiopathic disease. Hence it came to be believed that the death of the internal periosteum was a necessary prelude to necrosis, until it was observed that the parts surrounding a bone had assumed those actions which end in the formation of a new one before the absolute destruction of any part of the old one whatsoever; and therefore that, although the injury inflicted on the internal periosteum might cause necrosis, yet it was only one cause, and acted by creating inflammation within the substance of the bone. Thus we are obliged to return to the point from which we set out: we know that inflammation is established within the bone, and, coeval with this or nearly so, that nature commences the process of reproduction; but why this latter is confined to a limited period of our existence, or why even amongst young persons it may occur in one individual and not in another, form questions to which, in the present state of our knowledge, we can give no answer. We are not even agreed on the different steps of the process or on the structure principally engaged.

It has been observed that the portion of the bone which is to die, and for some space above and below it, is surrounded by a dense thickened mass, of rather a gelatinous character; that this mass, after a very short time, becomes opaque in detached spots, and that depositions of osseous material are found within it, so that a case of bone may be constructed around the original one before it actually dies, and thus the limb never be entirely deprived of support.* As soon as the dead bone separates from this surrounding mass, the internal surface of this new material becomes, under some circumstances, covered with a layer of lymph, and under others with regular ossific granulations, which gradually increase until a new bone is formed, nearly as serviceable, though not so symmetrical or so beautiful as the old one. It next becomes a question, what is this gelatinous mass, and whence is it derived? It has been supposed that it was the periosteum of the old bone swelled and thickened, and at the same time softened in consistence; and this opinion has been strengthened by Dr. Macartney,† the present Professor of Anatomy in the University of Dublin, who stated that he had opportunities of watching the progress of the disease from its earliest periods upwards. According to this gentleman, "the first and most important circumstance is the change that takes place in the organization of the periosteum: this membrane acquires the highest degree of vascularity, becomes considerably thickened, soft, spongy, and loosely adherent to the bone; the cellular substance, also, which is immediately connected with the periosteum, suffers a similar alteration: it puts on the appearance of being inflamed, its vessels enlarge, lymph is shed into its interstices, and it becomes consolidated with the periosteum." Next, "the newly organized periosteum, which, for the sake of distinction, one might call the vascular sheath or investment, separates entirely from the bone, after which it begins to remove the latter by absorption, and during the time that this process is carrying on, the surface of the vascular investment, which is applied to the bone, becomes covered with little eminences, exactly similar to the granulations of a common ulcer." To this doctrine Mr. Russell, of Edinburgh, strongly objected. He stated that if the osseous matter was deposited between the layers of periosteum, both the external and internal surfaces of the new deposit ought to be perfectly smooth, whereas the contrary is observed—they are rough, irregular, and one of them is covered with granulations. He instanced cases of fracture in which, one fragment overlapping the other, and being thus permanently entangled, the periosteum between the two can have no share in the reproduction, and yet the whole is united by a cylindrical shell of bone, on the principle of reproduction in necrosis. It is also known that compound fractures, where the fragments have been extensively stripped of periosteum, have united in the same way, and the regeneration of bone, in these instances, could not be attributed to periosteum, inasmuch as that had been destroyed. It must be owned that this is a very unusual occurrence in compound fractures, but one single example will be sufficient to prove that the reproduction *can* take place independently of the periosteum. And again, in cases where disease has caused the sloughing and destruction of the periosteum, as for instance in deeply seated paronychia, still reproduction is sometimes accomplished by a process resembling necrosis. These arguments seem to be very decisive in overturning the doctrine of the surrounding shell being formed by the periosteum, and accordingly Russell supposed that a deposition takes place from all the surrounding structures; that it is at first gelatinous; that it soon assumes the appearance of cartilage; and that at the end of twenty-four days bony specks may be discovered within it. The external surface of this deposit is rough, and attached to the surrounding parts: its thickness is quite unequal, being greater in proportion to the duration of the disease, and always more so than the bone it is destined to replace. The internal surface, or that next the old bone, is more smooth, and covered either with lymph or granulations. Boyer, Meckel, Weidmann, and other continental surgeons, attribute the process nearly altogether to the periosteum, and therefore their opinions need not be particularly discussed; but it is proper to mention that all the very accurate descriptions we read, of the progress from gelatine to cartilage and from cartilage to bone, must be received with the utmost caution. It is by no means usual to meet with cases exemplifying these descriptions; and amongst a considerable number of dissections of necrosis, it will perhaps be difficult to find one in which the existence of cartilage can be separately and distinctly shown.

Such is an outline of the chief opinions entertained on this interesting subject, and it is probable that, to a certain extent, they are all correct. When the periosteum has not been removed or spoiled, there can be no doubt that it is deeply and even principally engaged in the process of reproduction. In the museum a Park-street, the specimens exhibiting the earlies period of the disease show the periosteum a slightly thickened, smooth on its internal, bu more rough and flocculent on its external surface, detached from the bone, the surface o which is smooth, and scarcely appears change from its natural and healthy condition. At more advanced period, the periosteum is stil thicker, but is not softened; on the contrar it has nearly the firmness of ligament, an there are small osseous depositions within it the bone then being rough and uneven on i surface and evidently having lost its vitalit

* See Russell on Necrosis.

† See Crowther on White Swelling. Edition 1808, p. 183.

But although we concede to the periosteum the principal office in the process of reproduction, we can also conceive that the adjacent tissues are also more or less engaged, for the thickening of parts is found to extend on the outside of this membrane, and Dr. Macartney himself speaks of the cellular tissue external to the periosteum becoming altered and condensed. Now, supposing the periosteum to be destroyed, these structures may be capable of supplying its place and producing the secretion of gelatinous substance, which is afterwards to become bone, just as we see that if the periosteum is torn off a bone, the adjacent tissues laid down upon it may prevent exfoliation, and answer every purpose of nutrition and preservation that the original membrane did. From whatever source derived, this deposition begins while yet the original bone is in a state of inflammation, and the part that is to die still undetached. If tendons or muscles are inserted into this part of the bone, they, being living and organized substances, separate from that which is dead: but the previous deposition has extended about them, and fastened them in their situations, and hence not only is the limb capable of support during the progress of necrosis, but unless in exceedingly rapid, acute, and unfavourable cases, its motions may not be very materially impaired.

Soon after the investing shell has been formed, the dead portion of the bone separates from its attachments, and lies within its osseous case. It is now termed *the sequestrum*, and presents some remarkable and peculiar characters that distinguish it from diseased bone otherwise circumstanced. Its extremities are always jagged, pointed, and uneven: its marrow and internal periosteum have disappeared: its length and its diameter are always much less than ought to be anticipated from considering the size of the bone that has died; and its surface is uneven and marked with slight depressions, as if part of its substance had been taken up by the absorbents. This appearance is more distinctly observable, and the sequestrum is always smaller where the surface of the new shell is covered with granulation, than when it is only smeared over with lymph. And here, as in other cases, it may be observed that the existence of granulation or of lymph on the new bone seems greatly to depend on the free admission of air to the cavity. Where the bone is deep-seated, as in the thigh, and there are but a few sinuous apertures that can scarcely render the cavity analogous to an open sore, the surface is covered by a layer of lymph; but where it is more superficial, as when the shaft of the tibia has come away and left the new osseous deposit totally uncovered, its entire surface is seen studded over with healthy granulations, which, on passing the handle of a scalpel over them, are found to be gritty, and give sensible indications of containing bony matter.

From the first formation of the new deposit, small holes or perforations exist in it, the edges of which are bevelled down and thin, and notwithstanding that the new bone may and usually does become extremely thick and spongy, these apertures still remain thin: it is through them the matter makes its way to the surface and forms the fistulous ulcers that attend on this disease, and are to be described hereafter. These apertures remain as long as there is a single spicula of sequestrum within to keep up irritation and protract the suppuration. After the sequestrum has completely disappeared, the growth of osseous material still continues internally until the new shaft appears one solid mass devoid of any cancellated or medullary cavity whatever. At this period the ulcers are healed up, and the patient enjoys a wonderful use of his swollen and deformed limb, but the pathological condition of the bone is still deserving of attention. At first it is a mass of soft and spongy texture. After the lapse of a few years, though still clumsy in shape and undiminished in diameter, the bone has become much more firm and solid, and in these respects, at least, equals the original structure. At a more remote period the osseous part is wonderfully solidified, being, in some instances, as firm as ivory, and a new medullary cavity, with an internal periosteum, is formed. When a transverse section of a tibia so circumstanced is made, the osseous walls are found to be hard, thick, and very firm, the medullary cavity much narrower than in the healthy bone, being scarcely capable of admitting more than a goose-quill, and it does not seem to be cancellated or reticulated, but merely to consist of one continuous cell. In this state the bone possesses nearly three times the weight of one in the natural condition, and when dried is of a dirty brown colour, never assuming the white tint or polished appearance of the remainder of the skeleton.

Necrosis once formed is variable in its progress and indefinite as to the time that may be necessary to its completion. Sometimes the affection of the bone is exceedingly acute, accompanied by external inflammation resembling phlegmonoïd erysipelas: in these cases the bone soon dies, the sequestrum separates and protrudes very rapidly, perhaps even before the new deposit has attained strength to support the limb, so that it is necessary to preserve it artificially as to shape and length until the process is complete. Within the last year we have seen a case in which, through neglect of this precaution, the tibia is bent nearly into the shape of the letter C. In other instances the disease is extremely tedious, requiring years before the sequestrum is either removed or absorbed: we possess a preparation exhibiting a specimen of necrosis of more than six years' duration, in which the sequestrum is of a more than ordinary size. Between these extremes of great rapidity and as great tediousness there is every possible variety, and perhaps these medium cases are the most unfavourable, for the very rapid are over before the constitution is broken down, and the very slow produce their effects on the system so gradually as not to make any decided or severe impression; whilst those which exhibit the symptoms of abscess, with an extraneous body working to gain the surface and not able to accomplish it quickly, occasion much suffering, and if there is ever danger to life or limb from the disease, such cases are most likely to produce it.

The sequestrum or dead bone is disposed of either by presenting externally and permitting of its removal by the process of ulceration or by manual operation, or else it is never seen, and is entirely carried off by the absorbent vessels. Mr. Russell accounted for the disappearance of the sequestrum in a very unsatisfactory manner. He considered the dissolution of the dead bone to be "greatly accelerated by the solvent power of the purulent matter," a property, the existence of which in pus both observation and experiment render questionable: and when thus macerated, he conceived it to be prepared to be removed by absorption or washed out by the discharge of the matter. But, if the surfaces of a sequestrum are examined, that which is next to the granulations of the new bone will be found to be irregularly marked and indented, as if by the action of the mouths of the absorbents, whilst the other is comparatively smooth; and as every part exposed to the action of the fluid should suffer equally if the removal of the osseous particles was effected by maceration, there are strong reasons for believing that the disappearance of the sequestrum depends not on any power chemical or mechanical, but on some vital process, and therefore probably on the action of the absorbents.

When the sequestrum presents externally, either one end of the bone (almost always the superior one) protrudes through the soft parts and remains there dry, hard, and dead for a longer or shorter time, until it becomes detached by the slow process of nature, or is separated by a surgical operation; or else the middle of it presents, and can be seen or felt through an aperture in the surrounding new bone whilst its extremities are confined. In either case the process of removal is extremely tedious. When the end presents, it is generally moveable, and seems as if very little force would be sufficient to detach it altogether; yet if an attempt is made to pull it away, it is by no means easily accomplished, and a considerable time elapses between the first protrusion and its final and complete separation. When the middle presents, the process is still more protracted. All bones do not seem equally liable to necrosis. Perhaps the tibia is as frequently attacked as all the other bones of the skeleton taken together; next in frequency is the humerus, the bones of the fore-arm, the thigh, the clavicle, and lastly the lower jaw.

Thus far, it will be seen that we have considered necrosis as a disease, distinct and different from every other affection of the bones whatever, and that its chief and most marked characteristic is the process of regeneration. Regarded in this point of view, it is as much and even more an action of health than of disease, and it can easily be understood why the constitution suffers so little, why the hectic fever is of so mild and mitigated a form, and why in a simple and uncomplicated case recovery is nearly certain. It is also evident that this disease will not be likely to occur in a constitution contaminated with syphilis, scrofula, scurvy or any of those other vices which the continental surgeons not only think it may be united with, but which they adduce as its occasional exciting causes. Doubtless, if the death of a bone from any cause or under any circumstances—if caries, exfoliation, and other such destructive maladies are to be included as species under the generic name of necrosis, such affections may not be inconsistent with the existence of any poison or any taint; but if the idea of a process of reproduction coexistent with that of disease must be admitted as appertaining to this affection, it will be impossible to recognise scrofula or syphilis as connected with it in the remotest possible degree. Perhaps we shall incur censure for thus attempting to limit the signification of the term, but it has been observed that the nomenclature of surgical pathology is too loose and undefined, and in no instance is the remark more applicable than with reference to the diseases of the osseous system; and again, pathology to be useful must be practical, and we can by no means assimilate caries which is so destructive of the limb or fatal to life—or exfoliation, which is always attended with loss of substance—with necrosis, the essential character of which is a process of reproduction, and its natural termination recovery.

In attempting to describe, or even to arrange the remaining diseases of the osseous system, the pathologist has to encounter difficulties almost insurmountable. Some of these are natural to and inseparable from the subject, as 1st, the depth at which a bone may be situated will render it difficult to discover a change of shape or size, much more to ascertain an alteration of structure. 2d. The bones do not always exhibit a very active sensibility; when attacked by chronic forms of disease, they do not cause very great pain, and consequently the evil may be well established and irremediable before the patient is fully sensible of his condition. 3d. These affections are not fatal at an early period; they run a long and tedious course before they destroy life or render the removal of the limb indispensible. And hence in any individual case it may be difficult to learn even the early history or commencing symptoms, much more the nature of that peculiarity of constitution that disposes to these diseases, or the first changes that take place from a healthy to a morbid structure. Little, indeed, can be ascertained with certainty as to the nature of osseous tumours until the part has been removed, and then the information comes too late for any useful purpose. Another source of embarrassment exists in a want of accordance as to the nomenclature of these affections. One surgeon calls that exostosis which another has named osteo-sarcoma, and a third has designated as cellular exostosis an affection which he himself in another place has named spina ventosa. In order, in the present instance, to avoid similar confusion, we must endeavour to construct an arrangement which shall give to each class of disease its own generic term; and although occasionally such deviations from the usual operations of nature will present themselves to the pathologist as to baffle all his attempts at classification, still we believe such a foundation as we allude to will be eminently useful, whatever superstructure may be raised upon it.

Spina ventosa.—In our museums of morbid anatomy, there is no want of specimens exhibiting the separation, or rather expansion of the solid walls of a bone, leaving one or more cavities within it; these cavities having during the patient's life been filled with a secretion that presents considerable variety in different cases, sometimes possessing a moderate degree of firmness and consistency, but more frequently consisting of a fluid of a serous character and reddish colour. This is the disease to which we apply the name of spina ventosa in contradistinction to abscess within a bone, from which it differs in its extremely chronic nature and tedious progress; in its not containing purulent matter; in its having no tendency to burst into any contiguous joint; and (until at a very advanced period) in its not being complicated with caries.* Boyer divides this disease into two species, one of which is peculiar to children, and continues to the age of puberty; the other, the spina ventosa of adults, which exhibits the characteristic features of the disease more perfectly.

It is, indeed, difficult to separate the first-mentioned of these affections from our commonly-received notions of caries, and in the various instances we have seen we have always regarded them as such. Boyer attributes it to the influence of a scrofulous taint within the system, and says that it attacks the metacarpus, the metatarsus, and the phalanges. It commences and continues for a length of time either without pain or with very trivial suffering; the tumefaction of the parts is moderate, their motions scarcely interfered with, and recovery finally takes place about the age of puberty by a species of necrosis. Its course is thus described: "The progress of the disease and the distension the soft parts undergo, cause them to ulcerate at a spot always corresponding to some aperture in the osseous cylinder, and permitting the introduction of a probe within its cavity. The external aperture becomes fistulous, and for a long time discharges a moderate quantity of ill-digested serous matter. The part, however, remains indolent, the constitution does not suffer, and if the patient can thus attain that epoch of life at which nature commonly can struggle with success against scrofula, this form of spina ventosa may be cured by necrosis of a part of the spoiled bone. Then the sequestrum is detached, the remainder of the osseous parts subside, resolution is established, and the disease ends by a deep, adherent, and deformed cicatrix." We have not met with the affection as here described—we have never seen any thing like the regeneration of a bone thus lost, nor can we conceive necrosis, which is essentially a reproductive process, to be in anywise allied to or connected with scrofula; we therefore still regard this disease, which after all is not very frequent of occurrence in these countries, as a modification of caries.

"The other species, fortunately more rare but much more serious, most frequently attacks adult persons, and affects the extremities of the long and cylindrical bones of the limbs." Its exciting cause seems to be involved in utter obscurity, nothing being known with certainty concerning it. Very often the patient traces it to the receipt of some injury, but it occurs so frequently without any such provocation, that it must be considered as an idiopathic disease. It is found most frequently, as Boyer has remarked, in the long bones, where the medullary cavity is best developed, but it is seen in the flat bones also, and in so many instances in the lower jaw as to render it an object of attention with reference to this bone alone. Its commencement has no characteristic by which it can with certainty be known, and its progress is equally variable, being generally slow, but sometimes remarkably rapid. It commences with pain, occasionally deep and dull, occasionally severe to excess, either when its progress is rapid, or it presses on some sensible or important part. This pain, with very few exceptions, precedes the swelling, and when the disease attacks the lower jaw is almost constantly mistaken for common tooth-ache—a mistake that leads to the extraction of one or more of the teeth and the consequent exacerbation of morbid action. The tumour seems to engage the entire circumference of the bone, if it be a round one; if flat, the swelling is more oval, and sometimes it is irregular and lobulated. It is hard, firm, unyielding, and incompressible: pressure on it does not occasion an aggravation of pain, unless it shall have happened that the periosteum is inflamed, when of course the smallest pressure will occasion suffering. In the commencement it bears a strong resemblance to necrosis of the long bone, except in not being preceded or accompanied by fever, and in not being so painful or so rapid in its progress. In the flat bone it has a greater likeness to osteo-sarcoma, from which it is so difficult to distinguish it that many cases of spina ventosa have been operated on and removed as examples of the other disease. Nevertheless at a more advanced period the diagnosis is more easy, for spina ventosa does not reach the great, or rather the illimitable size to which osteo-sarcoma may attain.

In a pathological point of view, spina ventosa should not be considered as a malignant disease: it often endures for a length of time or during life without engaging adjoining structures or contaminating the constitution, and if removed by operation it does not recur in another place or seize on some other bone. It is, moreover, not infrequently capable of relief or even of cure by the simple operation of exposing the cavity and evacuating its contents. We have at this moment before us the details of a case in which the patient referred a

* Dict. des Sciences Médicales, tom. lii. p. 311.

spina ventosa of the lower jaw to a blow received *forty-one years previously*, during the last twelve of which the tumour had been opened or given way spontaneously three several times. In hospital it was punctured through the mouth, and found to consist of three distinct cells, each containing its own collection of a fluid of the consistence of oil, varying from a straw colour to that of coffee, the darkest being lodged within the largest cell. This patient, though at the advanced age of sixty-seven, was relieved by the operation, and left the hospital convalescent. If, however, by the term malignant is meant a disease that may prove destructive of life or limb, spina ventosa can occasionally lay claim to the title. For it sometimes happens that small dark red or purple elevations appear on the surface of the skin, which soon ulcerate and burst, discharging a quantity at first of the material contained within the bone, the character of which subsequently alters into a brown, unhealthy, fetid, and often putrid sanies. This ulceration is much more likely to take place when the surface of the tumour is uneven and lobulated, and at this period the disease in appearance bears no very faint resemblance to fungus hæmatodes. The external sores next become fistulous and fungoid; they lead down to the cavity or cavities within the bone, and the patient, worn and wasted by an ill-formed irritative hectic fever, sinks exhausted and dies.

Boyer* in his description recognizes these two forms of spina ventosa. "Sometimes," says this author, "having attained a size double or triple that of the natural dimension of the bone, the tumour ceases to make further progress: it no longer causes pain; it does not interfere with the motions of the part, but remains stationary, and continues thus during life, without any alteration of the soft parts, which accustom themselves by degrees to the state of distension in which they are placed. But much more commonly it continues to increase, until it slowly arrives at an enormous size, still preserving its inequalities of surface or acquiring new ones." Having proceeded to the period of ulceration, the conclusion of the case is thus delineated. "Arrived at this point, the local disease exercises a baneful influence on the constitution of the patient: the edges of the fistulous apertures become depressed and inverted towards the interior of the tumour; the discharge becomes every day more copious and more fetid; the fever which appears commonly at the period of ulceration, but which at first is intermittent and irregular, comes at last to be continued, and assumes the character of hectic: the pains are unceasing, and sometimes intolerable; sleep and appetite are deranged or lost; consumption establishes itself, and the patient dies exhausted and worn out."

Other authors, however, have considered spina ventosa in all its forms as a malignant disease. Such must have been the opinion of Mr. B. Bell,* of Edinburgh, not only from his descriptions, but from the practice he inculcates. "The treatment," he says, "of spina ventosa is very simple, as the surgeon, when he is insured of its existence, must at once have recourse to the amputating knife. If the disease is seated in the bones of the metacarpus or metatarsus, as is generally the case in childhood, they should be removed at the articulations. If it has attacked the tibia and fibula, or radius and ulna, the amputation may be performed either at the knee or elbow, or a short way above these joints. The general rule to be observed is, that the entire bone in which the disease has its seat should be removed."

The morbid anatomy of spina ventosa throws but imperfect light on its pathology, principally because the first and early changes induced by the disease are wholly unobserved, and therefore are we ignorant both of the peculiarity of constitution that disposes to it, and of the local alterations that are first developed. Even at a more advanced period, when an opportunity is afforded of examining the part after death or removal, there is no striking uniformity of appearance. The bone itself, as Boyer remarks, seldom seems to have suffered any actual loss of substance: on the contrary, it often appears rather to have gained in weight, the walls expanding and becoming thinner in proportion as the cavity within increases in size. As to the number, size, and shape of these cells, there is an infinite variety as well as in the appearance of the surface, which may be smooth, irregular, or lobulated, and in the character of the membrane lining the cells and the material secreted by it. There is in the museum of the Anatomical School, Park-street, Dublin, a very curious specimen, exhibiting a perfect bony cyst developed within a spina ventosa of the superior maxilla, and completely contained within the expanded walls of the bone. It is a very remarkable circumstance connected with these alterations of structure, that although they usually commence near the extremities of the long bones, they never attack the joints, and consequently the motions of the adjacent articulation may be but slightly impaired, even although the size of the tumour may be such as to interfere with the natural shape of the joint, and render its usual appearance obscure and indistinct.

Exostosis.—We employ this term to indicate certain tumours growing from the outer surface, or rather the external structure of a bone, in the production of which neither the medullary substance within nor the periosteum without have any participation. And although our notions of the nature of the disease may not be perfectly correct, and our descriptions lame and incomplete, we still prefer this arrangement in order to separate the disease under consideration from spina ventosa on the one hand, and osteo-sarcoma on the other. It will be necessary also to distinguish it from nodes and some other affections of the periosteum, in

* Loc. citat.

* Treatise on Diseases of the Bones, by Benjamin Bell, edit. 1828.

which a deposit is found between it and the bone, or between the laminæ of this membrane. Exostosis, then, may consist of different structures—of cartilage alone—of cartilage mixed with some material resembling ligament—of cartilage mixed with osseous structure, which is by far most frequent of occurrence—of pure bone—and lastly, of a much harder, firmer, and closer substance, nearly resembling ivory. It may attack any bone whether flat or round, and may be found in more than one bone at a time: perhaps the femur and the tibia are most frequently engaged.

Like most other affections of the osseous system, the causes that lead to the production of this disease are involved in the greatest obscurity. Unquestionably they sometimes appear as the results of accident, but then, when other and more severe injuries constantly occur without inducing such a consequence, the unavoidable conclusion must be that some peculiarity of constitution predisposing to the disease exists in the individuals who suffer from it. Exostosis has been seen, though not frequently, at a very early period of life; it has occurred idiopathically and attacked several bones in the same individual at the same time; after complete removal it has grown again with an inveterate pertinacity, and we have seen it in two or more individuals of the same family. Boyer* considers the venereal poison to be the most common cause of exostosis, scrofula to have but little connexion with it, and scurvy still less. Other French writers† take a more extensive range, and adduce as causes, accident, cutaneous affections, scrofula, scurvy, cancer, and venereal. We cannot coincide with any of these opinions. Scrofula, when it attacks a bone, produces a destructive caries, and not an adventitious growth; scurvy, a softness or brittleness of bone. If there is any idiopathic disease of bone bearing the smallest resemblance to cancer, it is osteo-sarcoma, and venereal or even mercury we suspect to have a closer connexion with caries than exostosis.

In every form of exostosis, no matter from what cause proceeding, (and we have seen that its exciting causes are sufficiently obscure,) the surface of the bone and its substance to some depth become altered into a structure nearly resembling that of the morbid growth. Pathologists are not agreed as to whether this alteration should be attributed in the first instance to an inflammatory process within the periosteum or the bone itself. Mr. Crampton‡ makes the terminations (as they are technically called) of chronic inflammation of the periosteum to consist in cartilaginous thickening of the membrane, absorption of the subjacent bone, or the deposition of an undue quantity of bony matter upon its surface, the first and last of which are evidently forms of exostosis. However, leaving this part of the subject, which after all is not of much practical importance, still unsettled, it may be remarked that whether the morbid action commences in the bone or not, this latter structure is always extensively engaged. Exostosis is seldom to be met with like a circumscribed tumour in the soft parts connected by a narrow neck or bounded by a well-defined base; on the contrary, the bone forms a considerable portion of the swelling, which generally seems to spring gradually from an extended portion of its surface.

The symptoms of exostosis may be arranged into those produced by the inflammatory or other diseased action within the bone or periosteum, and those occasioned by the pressure of the tumour on the adjacent organs. In general it is said not to be very painful nor very sensitive to the touch, but this opinion must be received with great limitation. We have witnessed the case of a young gentleman who had exostosis on the front of both tibiæ. Here was neither nerve to be compressed nor muscle to be interfered with, yet the pain was so great that he insisted on their removal. The part was as hard and firm as ivory, and removed by the mallet and chisel. His sufferings were extreme: he was subsequently attacked with erysipelas, and his life brought into extreme danger, yet did he not regret his pain and the risk he ran when considered as the price of the relief he had obtained. The pain in this case could not be regarded as the result of pressure on any very sensible structure.

However, the situation of the tumour may not only occasion a great aggravation of suffering, but be the cause of very formidable occurrences. We have seen a very small exostosis, not larger than half a marble, prove the apparently exciting cause of epilepsy, which for years embittered the patient's existence, and at length brought it to a termination. Indeed, it can scarcely be necessary to adduce instances in order to prove that morbid growths from the internal table of the skull may prove detrimental or even destructive in a variety of ways. Such growths from the bottom of the orbit very generally destroy vision by protruding the eye from its socket; from the maxillæ they may interfere with respiration or deglutition; and in any situation where there are muscles, they must more or less change their direction or otherwise impair their motions. But beyond this they cannot be considered as malignant—they do not involve adjacent structures in a disease similar to themselves, they do not ulcerate, neither do they contaminate the system through the medium of the absorbents. The vascular organization of an exostosis seems to be inferior to that of the bone from which it springs, and to the healthy structures whether bone or cartilage that it may appear to resemble; its growth is therefore in general slow and its size moderate; but its increase is progressive, and there is no limit to the size it may ultimately attain, in this respect differing from the node, which soon attains its proper dimensions and does not increase subsequently. The same deficiency of organization causes it to endure an attack of inflammation but badly, and therefore, when subjected to any irritation or even exposed to the influence of the atmos-

* Traité des Maladies Chirurgicales, tom. iii. p. 549.

† Dict. des Sciences Médicales, art. Exostose.

‡ Dub. Hosp. Rep. vol. ii. p. 433.

phere by the ulceration of the superincumbent tissues, it is prone to fall into mortification, which is one of the methods by which a natural cure may be accomplished. Not very long since a man was operated on in the Meath Hospital for the removal of an ivory-like exostosis from the tibia, but the tumour was so hard as to resist chisel and mallet and every instrument that could be employed, and, finally, the operation was abandoned; yet was the case ultimately successful, for the exposed tumour sloughed, exfoliated, and the patient left the hospital perfectly well.

It is remarkable that if the exostosis has been removed by operation, the same degree of certainty as to its not returning does not exist as when it has thus sloughed away. On the contrary, when the tumour has been completely extirpated and only the sound part of the bone left, a new growth is often formed with so much certainty and rapidity as to justify the expression we have already used, of its "growing again with an inveterate pertinacity." On this subject we recollect a story (told, we believe, by Bell) which might be considered as ludicrous if it was not but too instructive. A dancing-master had exostosis on both tibiæ; they gave him no inconvenience, but the deformity was intolerable to his eyes, and he thought it interfered with his popularity and therefore with his profits. He persuaded a surgeon to lay them bare and scrape them down to his ideas of genteel proportion, but unfortunately the surgeon forgot that bones could granulate and grow. They did so in this case, and after a long confinement and much suffering the last condition of the patient was worse than the first—the deformity was much increased.

We distinguish a node from a truly exostotic growth by the rapidity of its formation, by its becoming stationary when it has been formed, whereas the increase of exostosis is progressive and may be unlimited; by its being exquisitely tender to the touch; its being subject to nocturnal exacerbations, and by its capability of being relieved or removed by medicine in a great number of instances. When composed of osseous material alone, the almost stony hardness of an exostosis will serve to distinguish it, and when of cartilage, it is lobulated or nodulated on its surface, which is never the case with respect to nodes.

There is a fungoid disease of the periosteum which, under particular circumstances, may be mistaken for exostosis, an error which we have witnessed, and which might be attended with serious consequences. It is fortunately of very rare occurrence, and as far as we know has not been hitherto described. In the four specimens which have fallen within our observation, its situation has been in the periosteum of the tibia.

During life, when covered by a dense and resisting fascia, the tumour is very hard, its growth slow, and not attended with much pain; neither is the use of the limb much impaired, as we have known a patient with this disease travel on foot a distance of six miles to the hospital. When not so restrained, its growth is more rapid: it is softer to the feel, and has most of the external characters of malignant fungus. Frequently its surface is lobulated or otherwise uneven, when it very much resembles exostosis. When the skin gives way and ulcerates, or if the tumour is unfortunately cut into, a bleeding fungus protrudes, that runs rapidly into a gangrene, which involves the adjacent parts; and if the limb is not speedily removed, the patient dies.

When examined after death or removal, the tumour is found to be situated within the laminæ of the periosteum. There is a specimen in the museum of the school in Park-street, in which the membrane may be seen as if split, one layer passing in front of the diseased mass, and another still more distinctly, behind, between it and the bone. The consistence of the tumour is tolerably solid and firm, but not so solid as cartilage; its colour is white or gray, and its vascular organization apparently very deficient. This latter circumstance is very remarkable, for in some instances these tumours exhibit a pulsatility scarcely inferior to that of an aneurism, a symptom that may render diagnosis extremely difficult, and which cannot be explained by any post-mortem examination. The substance of the bone beneath the tumour is always removed by absorption to a considerable depth.

Osteo-sarcoma.—This disease, as its name implies, is a degeneration of the bone into a substance of a softer consistence, not, however, resembling flesh; or rather it is an alteration of structure accompanied by a deposition of new material, and therefore attended by tumefaction to a greater or less extent. As such, it is evidently irremediable except by the knife, and if there is a disease of the osseous system to which the term malignant can be applied, it certainly is this. Its malignancy, however, has no resemblance to that of cancer or fungus hæmatodes, although like the latter it very frequently attacks persons in the earlier periods of life; but it does not involve adjacent structures in a disease similar to itself, neither does it contaminate the system through the medium of absorption. The most terrific feature in its character is its tendency to recur after its removal from one situation, being in this respect more formidable than cancer, which is, in many instances, at first but a purely local disease, and may be extirpated with complete success. This predisposition to the disease is evidently constitutional, but as we are totally ignorant of the circumstances that conduce to it, and will probably remain so, it is wholly uncontrollable by medicine or medical treatment.

This disease may possibly affect persons at every period of life, although we have not seen it in the aged. In children, particularly about the fingers, the wrists, the fore-arm, &c. nodulated swellings are frequently met with of a large size and firm consistence, which go on progressively increasing until they arrive at a destructive termination to be described hereafter. On examination a tumour is found, the external surface of which is bone, as thin, it may be, as paper, and in some spots nearly entirely absorbed evidently shewing that the morbid action had commenced and increased from within; the substance of this newly-formed mass being neither cartilage nor ligament, but perhaps something between both, and yet not so entirely so as to deserve the name of ligamento-cartilaginous, or to be likened to any natural animal product whatever. It has been described by Bell as a substance much resembling callus.* Again, in another specimen as it appears in the adult, (in the lower jaw for instance,) the part of the bone in which the disease commenced is completely spoiled and changed into a mass of this new material, assuming a rotund tuberculated appearance. From thence downwards, towards the spot where the bone is not spoiled, there is an admixture of this new material with gritty particles of bone generally disposed in a radiated form; the entire containing cells filled here and there with a dark-coloured fluid, and traversed throughout by a foul and fetid ulceration. But osteo-sarcomatous tumours, although generally consisting of this firm material, are by no means so invariably. In one remarkable instance in which the disease occupied the femur, a vertical section of the inferior end, which was monstrously enlarged, exhibited a mass of much softer consistence, and cellulated or porous. Its colour was a mottled dark brown, and it resembled nothing so much as a dirty sponge that had been soaked in blood and matter. Sometimes the tumour is so soft as almost to resemble brain: sometimes there are cysts containing fluid like blood: in the long bones there is constantly a fracture in the centre of the tumour, or if the swelling occupies the shaft, the articulating surfaces are broken from it.† Very often this fracture is, or seems to be, the commencement of the disease.

We collect from these observations and dissections that osteo-sarcoma, as we understand the term, consists in a morbid alteration interesting the entire structure of a bone; commencing in its interior, and incapable of remedy or removal unless by amputation. We have already stated that its chief malignancy consisted in some constitutional predisposition which originally led to its formation, and induces a recurrence of it in some other situation after removal, and we wish to examine into the correctness of this opinion in order to separate it from cancer and fungus hæmatodes, because some diversity of opinion obtains on this part of the subject, which after all is the only one of practical importance. Boyer,‡ who considers malignancy as constituting the very essence of the disease, nevertheless recognizes two species. "In one, the osteo-sarcoma is propagated by the continuity of some cancerous affection, which had commenced in the adjacent soft parts, as is seen, for example, in the bones which form the walls of the nasal fossæ, and more particularly in the superior maxilla when they become spoiled as the result of a hard and cancerous polypus, which had previously existed for a long time insulated, and without any other local affection. In the second species the bone is the original seat of the disease, its own proper tissue is degenerated, and the surrounding soft parts only partake of the same species of alteration consecutively and in a secondary manner." Dupuytren,* in describing the disease as it attacks the lower jaw, offers pretty nearly a similar opinion. If, says he, the osteo-sarcoma is primitive, it remains a long time confined to the bone, and may acquire a very considerable volume before the lips and cheeks are affected. It then presents itself under *two principal forms:* in the one, the disease consists in cancerous fungi, which spring from the substance of the bone, within which the disease is often superficial, that is, it may only affect the alveolar edge or the surface, the body of the bone remaining without any enlargement, and particularly its base continuing sound. The second form is that in which the disease commences in the centre of the bone, which becomes *fleshy*, and swells throughout its entire thickness. Most tumours of this description acquire a considerable size, and occasion a most repulsive deformity. The teeth, loosened and displaced, appear implanted here and there in the substance of the bone. It is impossible to close the jaws. The lips, distended, thinned, and closely applied to the tumour, no longer retain the saliva, which trickles off continually. It is, however, worthy of remark that these tumours, or at least many of them, are slow to ulcerate or pass into the condition of cancer. Sir A. Cooper† has evidently made a similar division of osteo-sarcomatous tumours, and described them with his accustomed accuracy and clearness, but under the names of cartilaginous and fungous exostosis. Mr. Crampton,‡ in his paper on osteo-sarcoma, also divides it into two species, the "mild and the malignant," stating, at the same time, that the nature of either previous to dissection after removal or after death is involved in the greatest obscurity. He considers the encysted condition of the tumour, its lying in a bed of cellular tissue unconnected with the surrounding parts, as indicative of mildness: the characters of the malignant, as laid down by him, are evidently those of genuine carcinoma. "The soft bleeding fungus, which makes its way through the integuments before the tumour has acquired *any very considerable size;* the profuse and peculiarly fetid discharge, slightly tinged with the red particles of the blood; the tubercles of a purple colour on the surrounding skin, which adheres firmly to the subjacent tumour; the pain, and above all the altered health, sufficiently point out the malignant character of the disease."

We have thus laid before our readers the

* See Bell's Principles of Surgery, 4to edition, vol. iii. part 1.

† We have taken the above descriptions entirely from preparations in the school of Park-street, Dublin.

‡ Traité des Maladies Chirurgicales, tom. iii.

* Leçons Orales, tom. iv. p. 636.

† Cooper and Travers's Surgical Essays.

‡ Dub. Hosp. Reports, vol. iv.

opinions of the highest and most respectable authorities, although we cannot coincide with them in classing cancer as a species of osteo-sarcoma. Pathologically they are distinct and different diseases, appearing in patients of different ages, habits, and conditions of health, and exhibiting totally different phenomena; and practically they are not alike, for it would be as insane to attempt the removal of a bone contaminated by an adjacent cancer, as it would be cruel to refuse the chance of an operation to one afflicted with true osteo-sarcoma. The disease is only malignant in its tendency to re-appear, nor can it be previously ascertained by the symptoms, or subsequently by examination of the tumour, whether it is likely to show this disposition or not. Those nodulated tumours that occur on the fingers and wrists of children, and which are so admirably described and delineated by Bell,* almost invariably reappear in some other situation after removal. This we have seen remarkably exemplified in the case of a little girl who was admitted into hospital with the two fore-fingers and thumb affected with this disease: they were amputated, but in nine weeks afterwards both the radius and ulna were attacked, and the arm was cut off. In seven weeks both clavicles were engaged, and the little patient was sent to the country, from which she never returned. Besides the development at an early age, a rapidity of growth, accompanied by intensity of pain, is considered as indicative of a most unfavourable disposition in the system. Yet is the contrary no assurance of safety, for we have seen a case in which the disease had lasted for five years and without much suffering, return after removal, and destroy the patient in less than twelve months. In general, however, the remark seems to be grounded on experience. The presence of a deep and foul ulceration within the tumour is rather unpromising: in Mr. Cusack's six cases of excision of the lower jaw, the disease returned in one only, and in that this kind of ulcer had previously existed. It may, too, be laid down as an unvarying rule that the secondary appearance of osteo-sarcoma is more painful and more rapid in its progress than in its first and original attack. It is uniformly fatal.

The first approaches of osteo-sarcoma are usually insidious, and as it is in general not a very painful affection, it may (particularly in children) escape observation at its very earliest periods. Any bone may be attacked by it, but in the adult it is more frequently situated in the spongy extremities of the long bones and in the lower jaw, whilst the phalanges, carpal and metacarpal bones, the radius, the ulna, and the clavicle furnish the best and most frequent specimens in the younger subject. It occurs often idiopathically, and on the other hand it occasionally follows or seems to follow a fracture or other injury, as if the disposition existed in the system, and only required some stimulus to direct it to any one situation. It commences usually by a small, firm, immovable tubercular-like tumour appearing to spring from some part of the bone: soon after another of these may make its appearance, but these, in the first instance, are free from pain and insensible to pressure. As it increases, the pain assumes a dull and aching character, in the jaw frequently mistaken for tooth-ache, in other bones for rheumatism. The degree of suffering, however, is not a very strong characteristic, for it will depend on the rapidity of growth, the distension suffered, the sensibility of the parts compressed, and a number of other circumstances too obvious to require detail. In ordinary cases, it has been remarked that the pain observes a more than progressive increase with the size of the tumour, particularly if its growth has been accelerated by any accidental injury. In the advanced stages it is always severe, and in some instances dreadful. In one of Bell's cases, it is stated that there was no hour of the night or day in which the patient's wild cries could not be heard miles off. In most instances the sufferer is completely deprived of sleep, and in some he complains of nocturnal exacerbations.

Once formed, it grows with greater or less rapidity, often appearing stationary for some time, and then suddenly and quickly increasing: sometimes, on the contrary, it increases rapidly from the commencement, and we have removed an osteo-sarcoma of the lower jaw, which attained to the enormous weight of 4 lbs. 1 oz. avoirdupoise in the short space of eight months. Whilst the tumour is comparatively small, the skin is pale and glassy and stretched, and blue veins are seen meandering on its surface: when large, its colour is dark red, verging to purple, and multitudes of these little veins appear upon it. It is, generally, firm to the touch, solid and heavy; but occasionally an examination with the fingers discovers the osseous covering of the tumour to be very thin, and it yields on pressure with a peculiar sensation of elasticity, such as one might conceive parchment to convey if not stretched very tightly. At length it gives way, and a foul ulcer is formed, discharging an unhealthy fetid pus, often mixed with blood. The character usually attributed to this ulceration is fungoid, but we have never seen it thus. It commences generally in the centre of the tumour by a slough, and gradually makes its way outwards to burst by two or three apertures, and we have seen an immense osteo-sarcoma of the lower jaw completely traversed by ulceration, one opening being in the mouth and the other at the inferior and most depending part of the tumour. These ulcers are usually hollow, attended with loss of substance, and we have not observed one that could have been easily mistaken for fungus hæmatodes.

Independent of any malignancy inherent in the tumour, it is evident that osteo-sarcoma may destroy life by being so situated as to compress some important or even vital organ, more particularly if such situation precludes the possibility of removal by a surgical operation. Such, for instance, was Mr. Crampton's case, in which the diseased growth sprung from the roof of the

* Loc. citat.

orbit, projecting forwards on the eye-ball and backwards on the brain, both of which organs it must have destructively compressed.* We have seen an osteo-sarcoma of the lower jaw in a young boy occasion death by suffocation ; and another in a young female impede deglutition so entirely that she died or seemed to have died of actual starvation. This, however, was at a period before an operation for the removal of the jaw had been attempted, at least in this country, and both were considered as specimens of fungus hæmatodes.

When the tumour re-appears after operation, it does so in a very short space of time, often before the wound has cicatrized and healed; and as its situation is in the immediate neighbourhood of the former disease, the fungus protrudes through the wound, and seems to grow from it. In these cases the progress to a fatal termination, which is inevitable, is perhaps, fortunately for the patient, extremely rapid also. Indeed in all cases of relapse, the growth of the tumour goes on much more quickly than in the original disease, and the patient's sufferings are considerably augmented also. We have seen cases in which the pain was so intense and so unremitting, that, night or day, not a moment's rest could be obtained, even under the influence of the largest doses of opium that could be administered with safety.

Cancer. Fungus hæmatodes.—We have already more than expressed a doubt that either of these diseases ever originated in the osseous structure, or could be considered as properly appertaining to it, although it must be conceded that, in a few insulated cases, a cancerous disposition has *seemed* to produce a fragility of bones, and that this loss of the power of resistance has preceded the development of the disease in the softer structures. But with the utmost diligence of research we have not been able to discover one case in which a morbid alteration of structure, analogous to those changes in the soft parts which we call cancer, and which contaminate the system through the medium of the soft parts, has been found within the bone itself, or indeed to have existence therein, independent of some similar degeneration in the adjacent structures. On this subject, however, our knowledge must be extremely limited. We do not well know what cancer is, or what is meant by a cancerous diathesis. We know not how to define or even to describe it as a generic form of disease. The dissection of these tumours exhibits an almost infinite diversity of structure, and during life, previous to the actual contamination of the system, when the information too frequently avails but little, it is difficult to say whether any given tumour possesses this quality of malignancy or not. We therefore do not offer a very positive or decided opinion on this subject.

But that the bones in the vicinity of cancerous disease often suffer from a malignaut and incurable species of caries, quite distinct and separate from that absorption which might be the result of pressure, and that this caries illustrates Mr. Hunter's position of the existence of a cancerous disposition in parts apparently sound, which will afterwards become developed even though the cancer is removed by operation, admits, we think, of most irrefragable proof. Several years since, we removed a very large cancerous ulceration involving most of the under lip, the angle of the mouth, and part of the upper lip also. The diseased parts were most unsparingly taken away, and a minute and careful examination could not detect the smallest hardness in any part of the extensive resulting wound. Nevertheless, in less than a year afterwards a tumour appeared at the angle of the jaw, with a hard and unyielding band striking from it deeply into the neck. The tumour increased and pressed deeply: an operation was altogether out of the question, and the man died of open cancerous ulceration. On dissection the bone was found to be deeply and extensively eaten away by caries: its entire structure was preternaturally softened, and on attempting to dry it, as an anatomical preparation, its earthy material crumbled away and was altogether lost. At this moment we have another case affording a similar example of cancer attacking the lower jaw after being apparently removed from the lip. The bone is swollen, hard, nodulated, and extremely painful; but notwithstanding the urgent entreaties of the poor man, no operation can be performed, and he too will die of open cancer. But the point is too well understood by operating surgeons to require further elucidation. Every one must have met with cases of extirpation of the breast where the ribs had been found softened and diseased, although little indication might have previously existed of such an unfortunate complication.

But with reference to fungus hæmatodes the question is by no means so easily settled. In very many cases of extirpation of the eye in consequence of this disease, the bones of the orbit, even at a very early period, have been found softened, altered, and spoiled, new and more irritable growths have sprung from their substance, and the affection has re-appeared in a worse, because a more incurable form. Operations about the upper jaw have too frequently proved failures from a similar cause. Again, although the immediate points of reference have escaped our recollection, we have read of cases of fungus hæmotodes, the very first and earliest symptom of which was a fracture of the bone or bones of the member in which the disease afterwards was extensively developed. In our own note-book are two such cases. One, a poor boy admitted into the Meath Hospital in the year 1820, with the most frightful enlargement of the thigh perhaps ever witnessed, the circumference of the limb being much larger than that of the body of an ordinary man. He attributed the disease to the almost spontaneous breaking of the thigh-bone whilst he was riding on an ass. The tumour never ulcerated, but as an operation, even at the hip-joint, was decided on in consultation to be practicable, he left the

* Dub. Hosp. Reports, vol. iv.

hospital, went to the country, and was lost sight of. A case nearly similar occurred shortly afterwards in the shoulder of a young woman, the first symptom of which seemed to have been a fracture of the humerus. Both these cases were at the time regarded as specimens of fungus hæmatodes, and as they were not examined, the question must still remain undetermined; but from what we have since observed, we should be disposed to think they were osteo-sarcoma. It is, perhaps, right to state that many surgeons of high attainments and great experience do not separate these diseases in their own minds, and still regard the affection of the bone, which we would entitle osteo-sarcoma, as a species of fungus hæmatodes.

It is, however, only in the first and middle stages that these morbid growths can be easily confounded one with the other. Both appear small at first, but increase with great rapidity; and both attain a size not often observed in other tumours, the fatty tumour alone excepted. The same purple colour, the same meandering of blue veins, and the same inequality of surface are found on both; and when the osteo-sarcoma is about to ulcerate, it may be observed to be soft in some places and firm in others, like fungus hæmatodes. But here the resemblance ends. Throughout the entire case the osteo-sarcoma is harder, firmer, and more unyielding: it attains to a much greater size previous to ulceration, and when ulcerated it does not shoot out (at least in its more common forms) a soft and spongy and bleeding fungus; neither does it destroy its victim with such rapidity.

In the Repertoire Générale d'Anatomie et de Physiologie Pathologiques (4 trimestre de 1826), there is an account of a disease of the tibia related by Lallemand and commented on by Breschet, who considered it to be some species of aneurismal tumour, more particularly as it is stated to have been cured by the application of a ligature on the femoral artery. The precise nature of this tumour, however, is only conjectural, as it was never demonstrated by dissection; neither is it right in the present state of our knowledge to question the correctness of these authors' opinions. Nature sometimes makes extraordinary deviations from the ordinary courses both of disease and recovery, and the circumstance of our inability to explain the processes adopted by her is not sufficient to warrant a denial of their existence. It may, however, be remarked that if the case alluded to was, as is said, an aneurism situated within a bony case and cured by the operation already stated, such recovery must have been based on principles totally different from those on which an artery is tied in an ordinary case of aneurism.

In the museum of the school in Park-street, there is a preparation perhaps in some degree illustrative of this cellulated aneurismal disease. It exhibits a morbid expansion of the walls of a humerus removed from a woman in Stevens's Hospital: the entire shaft of the bone seems to have been engaged, and the transverse diameter of the tumour is about five inches and a half. Within are a number of cells lined by a vascular membrane of an exceedingly dark red colour, the deep tinge of which has scarcely been weakened by the immersion of the preparation in fluid for more than seven years; and it is known that during life this enormous tumour imparted an indistinct sense of pulsation. It appears by no means improbable that the commencement of this disease was in the medullary membrane, which gradually became altered and poured out the material, whether blood or otherwise, with which its cells were filled. In proportion as this accumulated, the cells must have enlarged and the bone swelled. In many places the external parietes are seen thinned down to the strength of parchment or paper, and had the disease been allowed to progress, they might have been removed by absorption. Had such an event occurred, and the integuments subsequently given way, it is easy to conceive that a fungus might have sprung from this vascular membrane, which, occasionally pouring forth an abundant and incontrollable flow of blood, would in every particular have so far resembled fungus hæmatodes, that even an experienced practitioner might have found it difficult to distinguish between them.

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(*W. H. Porter.*)

BRACHIAL OR HUMERAL ARTERY (*arteria brachialis, humeraria*. Germ. *die Armarterie.*) This artery is the continuation of the trunk of the axillary. It commences at the inferior margin of the tendons of the teres major and latissimus dorsi, whence it extends to about an inch below the bend of the elbow, where it usually divides into the radial and ulnar arteries; but not unfrequently this division takes place high in the arm.

The brachial artery lies on the internal side of the arm above, but in its course downwards it gradually advances in an oblique direction until it gets completely to the anterior surface of the limb, where it is found situated nearly midway between the condyles of the humerus in front of the elbow joint; it is superficial in the whole line of its course, in every part of which its pulsations can easily be felt, and sometimes, in the arms of thin persons, are distinctly visible.

Relations.—*Anteriorly* the brachial artery is overlapped, for about its upper fourth, by the coraco-brachialis muscle and the median nerve; for the greater part of its course down the arm it is covered by the brachial aponeurosis, to which is added, where it crosses the elbow, the falciform expansion sent off from the tendon of the biceps to the internal condyle: the median basilic vein also lies in front of it opposite the bend of the elbow. *Posteriorly*, for about a third of its length from its commencement it lies in front of the triceps, from which it is separated by a quantity of loose cellular tissue which envelopes the musculo-spiral nerve; in its inferior two-thirds it rests on the brachiæus anticus. *Internally* it is covered by the brachial aponeurosis at its superior part, where the ulnar nerve is also in contact with it. The median nerve which crosses it, sometimes superficially, and at other times passing more deeply, in the middle of the arm gets to its internal side, and continues to hold this relation to it in the remainder of its course. *Externally* it lies at first on the internal side of the humerus, from which it is separated as it descends by the thin muscular expansion in which the coraco-brachialis terminates at the lower part of its insertion; in the remainder of its course the inner edge of the biceps bounds it. The fleshy belly of this muscle also partially covers it in front, a little below the middle of the arm. At the bend of the elbow, the relations of the brachial artery become more numerous and complicated; here it inclines obliquely outwards and backwards, and sinks into a space which is bounded on the inner side by the origins of the pronator and flexor muscles of the forearm, and on the outside by those of the supinators and extensors, the floor of which space is formed by the brachiæus anticus muscle, from which the artery is separated by a layer of adipose cellular membrane. The artery is accompanied in its passage into this space by the tendon of the biceps and the median nerve, the former being situated to its radial side, the latter to its ulnar; and it is at the bottom of this space, opposite the coronoid process of the ulna, that the subdivision of the artery into radial and ulnar usually takes place. As it enters the space the artery is crossed by the semilunar fascia of the biceps, by which it is separated from the internal cutaneous nerve and median basilic vein. (For further particulars on this stage of the artery, see Elbow, Region of the.)

Two venæ comites accompany the brachial artery: they are included in its sheath, and lie one on either side of it, often communicating by several transverse branches which cross the artery in front.

So superficial is the position of this artery from its origin till it enters the region of the bend of the elbow, that it may be exposed during life in any part of its course with facility, and, if the operator use only common caution, with safety. In all this course the artery may be felt, and in the upper third the operator may avail himself of the inner side of the coraco-brachialis muscle as a guide, and in the middle third, of the inner edge of the belly of the biceps. In both situations the operator has to avoid injuring the cutaneous nerves, and the median and ulnar nerves, as well as the basilic vein, which sometimes passes up as high as the axilla. He should also bear in mind the position of the inferior profunda artery, which is sometimes of a large size; and from its direction, as well as its relation to the ulnar nerve, presents a considerable resemblance to the brachial trunk.

Branches.—The brachial artery furnishes a variable number of branches from its external side, none of which is of sufficient importance to be distinguished by a name; they are distributed to the os humeri, the deltoid, coraco-brachialis, biceps, and brachiæus anticus muscles, and to the integuments. From its internal side, however, there usually arise, in addition to several small twigs sent to the triceps, teres major, latissimus dorsi, and the integuments, three branches of more considerable size, and which derive their principal importance from being the leading channels of anastomosis between the brachial trunk and the arteries of the forearm. These are, 1, the superior profunda, 2, the inferior profunda, 3, the anastomotica magna.*

1. The *superior profunda (profunda humeri*, Haller and Sœmm. *collaterale externe*, Boyer, *grand musculaire du bras*, Chauss.) arises from the posterior side of the brachial artery, close to the border of the axilla. It sometimes comes from the axillary artery by a trunk common to it and the posterior circumflex, and occasionally it arises from the subscapular. Immediately after its origin the profunda superior gives several branches to the coraco-brachialis, triceps, latissimus dorsi, teres major, and deltoid muscles. Some of these latter, ascending towards the acromion process of the scapula, anastomose with the thoracica acromialis, supra-scapular and posterior circumflex; while the branches sent to the latissimus dorsi and teres major anastomose with the subscapular artery. The supe-

* Sometimes the subscapular, and one or both of the circumflex arteries, derive their origin from the brachial.

rior profunda passes backwards between the os humeri and the long head of the triceps, and in company with the musculo-spiral nerve enters the spiral groove on the posterior surface of the bone, passing between the second and third heads of the triceps. About the middle of the arm it divides into two branches, the internal or ulnar, and the external or radial. The ulnar branch descends in the substance of the triceps to the olecranon process, around which it anastomoses with the posterior ulnar and interosseous recurrent arteries, having in its course supplied the triceps with several branches. The radial branch comes forward with the musculo-spiral nerve as far as the external intermuscular ligament, where it separates from the nerve and taking a more superficial course, descends along the outer margin of the humerus over the supinator radii longus and the triceps, to which and the integuments it gives several branches. On arriving at the external condyle it gives branches to the elbow-joint, and anastomoses with the radial recurrent in front, and the recurrent of the interosseous artery posteriorly.

Below the origin of the superior profunda a small artery, called *nutritia humeri*, frequently arises either from the superior profunda or the brachial trunk: it enters the nutritious foramen of the humerus, and is distributed to the cancellated structure of that bone.

2. The *inferior profunda (ramus alius posterior humeri*, Haller) arises from the internal side of the brachial artery, generally about the lower part of the insertion of the coraco-brachialis into the os humeri; passing backwards, it perforates the internal intermuscular ligament, behind which it descends, having the ulnar nerve internal to it until it arrives at the posterior side of the internal condyle, in the grooved depression between which and the olecranon it lies close on the periosteum, and is covered by the ulnar nerve: here it divides into several branches, some of which are distributed to the elbow joint and the muscles attached to the internal condyle and olecranon, and it anastomoses freely with the posterior ulnar recurrent artery. Sometimes the inferior profunda is a branch of the superior artery of that name; it varies very much as to its size in different subjects, being sometimes a very insignificant twig, while in other instances it is so large that it is liable to be mistaken by an operator for the brachial trunk. In reference to this latter circumstance Professor Harrison observes,* "In the dissected arm, the inferior profunda artery appears at some distance from the brachial, but if the triceps be pressed forward towards the biceps, so as to place these muscles as nearly as possible in their natural relations, those vessels will be found very close to each other; so that, in cutting down upon the brachial artery in the middle of the arm, in the living subject, the inferior profunda, from its situation, and from its being accompanied by the ulnar nerve, may be mistaken for the brachial. This error, however, may be avoided by recollecting that the brachial artery is the nearest to the triceps, and is a little covered by that muscle: in general, also, there is a material difference in size between the two vessels."

The remarks contained in the foregoing quotation do not apply to a merely hypothetical case, but to one which has actually occurred in practice, the following instance of which I once had an opportunity of witnessing. A late eminent surgeon undertook to tie the brachial artery for the cure of an aneurism at the bend of the elbow: the inferior profunda, which was unusually large, was exposed and tied on the supposition of its being the brachial artery, the pulsation in the tumour continuing undiminished pointed out the nature of the mistake which had been committed, and the patient had to submit to a second operation at a subsequent period, in which the brachial artery was tied with a successful result as to the cure of the aneurism.*

3. The *anastomotica magna, (ramus anastomoticus*, Haller, *collaterale du coude*, Ch.) arises generally at nearly a right angle from the inner side of the brachial, at a little distance above the elbow-joint. Several similar vessels, but of much smaller size, arise from the same source in its vicinity: at first it passes inwards across the brachiæus anticus, and perforates the internal intermuscular ligament, giving branches to the brachiæus anticus, the triceps, the cellular tissue and lymphatics above the internal condyle: having got upon the triceps, it descends to the back part of the internal condyle, where it anastomoses with the inferior profunda and posterior ulnar recurrent arteries. When the inferior profunda happens to be very small, or is absent, this vessel supplies its place by giving branches to the articulation, to the muscles attached to the internal condyle, and for anastomosis with the posterior ulnar recurrent. Where the anastomotica magna is absent, small branches from the brachial, inferior profunda, and ulnar recurrent arteries, supply its place. When a high division of the brachial artery occurs, the branch which is to become the ulnar usually gives off the two profundæ, and the anastomotica magna: this last, however, sometimes comes from the radial in such cases.†

† Surgical Anat. of the Arteries, vol. i. p. 176.

* [Such a mistake as that alluded to in the text may likewise occur where there has been a high bifurcation of the brachial artery.—Ed.]

† [The frequent occurrence of irregularity as to the position at which the brachial trunk divides into its terminal branches, the radial and ulnar, constitutes a point of great interest in the anatomical history of this artery. I believe it may be said that it never happens that the bifurcation takes place *below* the coronoid process of the ulna; on the contrary, the division above that point is by no means uncommon, occurring, according to the calculation of Professor Harrison, once in every four subjects. This bifurcation occurs at all points in the arm, and in some cases the radial and ulnar arteries proceed at once from the axillary. In general the anomalous artery is the radial, and is subcutaneous in its course, while the ulnar follows the normal course of the brachial trunk. Sometimes the reverse is the case: sometimes both radial and ulnar are subcutaneous, and sometimes the radial is at its origin ulnad, but afterwards crosses the ulnar artery at a very acute angle, to get to the radial side. In some rare cases the brachial artery is regular in its course,

Anastomoses.—The ascending branches of the superior profunda anastomose in the substance of the deltoid muscle with the anterior and posterior circumflex and the cephalic branch of the acromial thoracic, and with the subscapular and the axillary branches of the thoracica longior in the axilla. If the brachial artery be obliterated by disease or the application of a ligature above the origin of the superior profunda, the blood will be carried by the circuitous route of these anastomoses into the brachial artery and all its branches from the superior profunda downwards.

When the brachial artery is obliterated near the elbow, the circulation is maintained in the forearm and hand by the anastomoses of both profundæ and the anastomotica magna with the recurrent branches of the radial, ulnar, and interosseous arteries. The anastomosis kept up between all the branches of the brachial artery aloug the periosteum of the humerus, in the substance of the muscles and in the integuments of the arm, is so free as to be sufficient to ensure the circulation in the limb even if the brachial artery were obliterated throughout the whole of its length.

For the BIBLIOGRAPHY, see that of ANATOMY (INTRODUCTION) and of ARTERY.

(J. Hart.)

BRAIN. See ENKEPHALON, and NERVOUS SYSTEM (COMP. ANAT.)

BURSÆ MUCOSÆ. (Fr. *bourses synoviales;* Germ. die *Shleimbeutel.*)—This name was first given by Albinus to small shut sacs, filled with an unctuous fluid, which he found in certain parts of the body, interposed between the tendons and bones. The name, however, is now much more extensively applied, for anatomists have ascertained that those smooth membranes, previously noticed by Winslow, covering the tendons and lining the tendinous sheaths about the wrists and ankles, are strictly of the same nature as those described by the Dutch anatomist. The number of bursæ known to Albinus, and described by him in his "Historia Musculorum," was but sixteen pairs. Monro, who first properly explained their anatomy and uses in his excellent monograph upon this subject, has made us acquainted with no less than seventy pairs, all situated in the extremities: and since his day the number has been further increased by the discoveries of Beclard and others: so that anatomists are now acquainted with upwards of one hundred pairs, many of them situated in the head and trunk.

Bursæ mucosæ, though of the same structure and answering the same ends in every situation where they occur, may nevertheless be divided, with advantage, into two great classes; viz., I. the *subcutaneous bursæ,* or those placed between the skin and fascia; and, II. the *deep bursæ,* or those which lie beneath the latter membrane.

I. The *subcutaneous* or *superficial bursæ* were unknown not only to Albinus, but even to Monro and Bichat; at least there is no mention made of them in the works of any of these authors. Beclard, in his "Additions to the General Anatomy of Bichat," appears to be the first anatomist who refers distinctly to them. The most remarkable are,—1, a large one placed between the skin and the ligamentum patellæ; 2, one between the skin and fascia covering the great trochanter of the femur; 3, one between the skin and fascia over the olecranon. These are all extremely well marked. There are others likewise, which, though less perfectly developed, are, however, evidently of the same nature; such as that between the skin and fascia over the angle of the lower jaw, and those found upon the dorsum of the hand beneath the phalangeal and metacarpo-phalangeal articulations. These superficial bursæ are not equally perfect in all individuals: they are best developed in those whose limbs are actively and habitually exercised. On cutting into their cavities we generally find them traversed by numerous filaments: the appearance indeed is extremely similar to that presented by the subcutaneous cellular tissue in certain parts of the body,—in the palpebra and penis, for example; and this no doubt is the reason why these bursæ were not distinguished from cellular membrane by Monro and others. That they are different structures, however, or at least that they are independent of the cellular system, is sufficiently proved by the simple process of inflating their cavities through a small opening made into them; we then find that the air is circumscribed within a definite boundary, and cannot, as in the palpebra and penis, be made to pass into the surrounding cellular membrane.

II. The *deep bursæ,* or those placed beneath the fascia, are much more numerous and much better marked than the preceding. They are almost uniformly found in connexion with tendons, and, generally speaking, are interposed between them and the bones over which they play. Like the superficial ones, they too are always shut sacs, in most instances of an extremely simple form, but in some cases much more complex; and hence they may with propriety be subdivided into two sets,—the vesicular and the vaginal.

a. The *deep vesicular bursæ,* when fully distended, represent each a simple globular bag, one of whose sides is in contact with the bone, and the other with one side of the tendon, without, however, enveloping it. (See *fig.* 111, *b.*) On opening into its cavity, it is found to contain a viscid fluid, more or less abundant, and this is sometimes traversed by filaments passing from one wall of the sac to the other. They generally occur in the neighbourhood of the great articulations of

but gives off the interosseous high up, which has all the appearance and many of the dangers of the high bifurcation. Mr. Harrison mentions a case in which the brachial divided into three branches, two of which united to form the radial, which gave off the anterior interosseous, the posterior being derived from the third, the ulnar. Mr. Burns remarks, that when, as rarely happens, the ulnar is the anomalous branch, the bifurcation generally takes place nearer the axilla, than when the radial is the abnormal vessel.—ED.]

the hip, shoulder, knee, and ankle, but are not, as it was supposed until of late years, confined to the extremities, for we shall presently point out instances of their occurrence both in the head and trunk. Amongst the most remarkable in the inferior extremity we find, in the neighbourhood of the hip-joint, a very large one between the tendon of the psoas muscle and the capsular ligament; a large one between the great trochanter and gluteus maximus; one betwcen the gluteus maximus and vastus externus; one between the gluteus medius and trochanter; one between the gluteus minimus and trochanter; one between the pectineus and femur. These are all large and regular in their existence; but there are other smaller ones frequently met with, particularly at the posterior part of the joint connected with the small tendons and muscles placed there. About the knee-joint there are likewise several vesicular bursæ: immediately above the articulation, between the extensors and front of the femur, there is an extremely large one, oftentimes extending several inches upwards, and still more remarkable in many instances for communicating with the synovial membrane of the joint; a fact which has been well appealed to by the general anatomist in proof of the anatomical identity of these two structures. There is a large one, likewise, at the inner and lower part of the articulation between the tibia and the tendons of the sartorius, graeilis and semi-tendinosus: posteriorly between the origins of the gastrocnemii and the bone there is also found a bursa; and a similar one between the popliteus muscle and the joint. These, like the large one in front, generally communicate freely with the articular synovial membrane. There is also a bursa generally found between the semi-membranosus and the internal lateral ligament. Around the ankle there are but few vesicular bursæ: posteriorly, however, between the tendo Achillis and os calcis, there is found a very large one; and smaller oncs are frequently met with connected with the flexor pollicis longus, and some of the other muscles in their passage here. In the *superior extremity* we find, likewise, several vesicular bursæ: around the shoulder-joint there is a very large and regular one placed between the deltoid muscle and the capsular ligament; there is one between the clavicle and coracoid process; one between the scapula and subscapular muscle; one between the subscapular muscle and the capsule. Lower down there is a bursa between the humerus and the tendons of the teres major and latissimus dorsi; and also a bursa frequently between these two tendons, at a little distance from their insertion. About the elbow-joint there is a vesicular bursa between the tendon of the triceps and the olecranon; one in front, between the tendon of the biceps and the tubercle of the radius: there is also one between the head of the radius behind, and the extensor muscles passing over it. Around the wrist-joint there are no vesicular bursæ of any size or importance. There is in the trunk a large vesicular bursa, usually found between the latissimus dorsi and seapula. In the head we often sec a distinct bursa interposed between the two divisions of the masseter muscle.

b. The *deep vaginal bursæ* are invariably found connected with tendons and with the fibrous sheaths through which these tendons are transmitted. They are somewhat more complex than the preceding, for instead of representing a simple shut sac, they form, like serous membranes, by reflexion a double sac, one of whose portions, corresponding, for example, to the plura costalis, lines the interior of the fibrous sheath, while the other, answering to the plura pulmonalis, invests the surface of the tendon. There is, however, this difference between the pleuræ and the synovial sac, that in the latter there is no longitudinal septum, no mediastinum resulting from the reflexion of the membrane; for the reflexion occurs not along the channel, but at either extremity of the fibrous sheath: thus the bursa, if completely detached from all surrounding structures, would represent a large tube, containing within itself a smaller one; these two being continuous by their extremities alone.

The deep vaginal bursæ generally occur in the neighbourhood of ginglymoid articulations, and by far the largest and most interesting are those connected with the flexor tendons of the wrist and ankle. They are always of very great size, not only passing a considerable way upwards upon the forearm and leg, but likewise extending downwards into the palm of the hand and sole of the foot, and branching out at their distant extremity into several distinct sheaths for the respective tendons belonging to the different toes and fingers. Upon the phalanges the synovial sheath is firmly bound down by a dense unyielding fibrous membrane, a circumstance well worthy of remark; for, as we shall presently see, it modifies in a very important degree the characters of inflammation occurring here. Besides these, wc have a remarkable vaginal bursa connected with the long head of the biceps muscle; and smaller ones are found investing the tendons of the circumflexus palati, obturator internus, &c.

Having thus considered the forms and relations of the different sorts of bursæ, we may next proceed to offer a fcw remarks applicable alike to all, upon their structure, contents, uses, development, and diseases. Here, however, our labour is much abridged by the fact already alluded to, and now admitted upon all hands, that the membrane forming the bursæ, and the synovial membrane of joints, are anatomically and physiologically the same. They are, in fact, the same in form, being both shut sacs; the same in structure, being both essentially composed of cellular membrane; the same in function, for they are both designed to facilitate the motion of contiguous organs; and, as we shall presently see, they are both similarly affected by disease. Were we to enter at length into these particulars upon the present occasion, we should but anticipate details belonging properly to a more general head, that, namely, of *synovial membrane*. Hence the few remarks we are now about to offer must be received as merely supplementary to those found under that article.

1. *Structure.*—The opinion of Haller, that these membranes are ultimately composed of cellular substance, though controverted by Monro and others, is, however, now universally admitted. They are, in fact, like all synovial membranes, essentially composed of cellular substance, entirely destitute of fibre, scantily supplied with vessels, and remarkable for their softness and flexibility. The vaginal bursæ are, however, much more delicate than the vesicular. The fatty bundles, mistaken by Havers for glands, are frequently found in their substance. Rosenmüller speaks of distinct synovial follicles as likewise demonstrable, but the existence of any such bodies appears to us more than doubtful.

2. *Contents.*—Experiments have been made by Monro and others, to shew that the fluid contained in bursæ is similar to that contained in synovial membranes. These, however, may now be looked upon as superfluous, inasmuch as this question has merged in the general one, viz., the identity of the two structures. Chemistry, in fact, has proved that their fluid and that of synovial membranes are, if not completely, at least essentially the same. In the subcutaneous bursæ it is scanty and thin; in the larger and deeper ones it is said to be somewhat more viscid.

3. *Function.*—The use of bursæ is in all cases the same; they serve to isolate certain parts and facilitate the motions performed by them: hence they are found only in those situations which are the seat of motion. Their fluid, from its oily consistence, must of course tend considerably to diminish the effects of friction.

4. *Development.*—Bursæ are developed at a very early period, and are relatively more pliant and perfect in the child than in the adult, to facilitate, as it would appear, the almost incessant movements natural to that period of life. They become more dense and unyielding in the adult, and in extreme old age are said to become dry and rigid. This, no doubt, is amongst the causes which render the movements of old age slow and laboured. A curious fact connected with this subject is the accidental development of bursæ in cases where their presence becomes necessary. When the superficial bursa in front of the patella has been removed by operation, its place is ultimately supplied, as Sir Benjamin Brodie has seen, by a newly formed one, similar in every respect to the original sac. In cases of club-foot a large subcutaneous bursa has been found developed upon that portion of the swelling which has been the chief seat of pressure and motion: and in cases of diseased spine, attended with considerable angular curvature, a bursa has become developed between the projecting spinous process and the skin.

Pathological conditions of bursæ mucosæ.—Bursæ mucosæ, superficial as well as deep, are not unfrequently the seat of inflammation, resulting either from external causes, such as cold or local injury, or from constitutional causes. In the majority of cases inflammation in these structures assumes a chronic form, and its ordinary effects are either to increase the quantity of the synovial fluid, to determine the effusion of a turbid serum loaded with flakes of lymph, or to end in the formation of matter.

The general phenomena of bursal inflammation may be studied with most advantage in the large subcutaneous bursa in front of the knee-joint: it is more frequently inflamed than any other in the system. This, however, is not owing to any peculiarity of structure predisposing it to disease, but merely to the accidental circumstance of its situation, which exposes it more than any other to external injury. In those persons who continue for a long time in the kneeling attitude, in devotional exercises for example, and still more remarkably in those whose occupation obliges them not only to support the body but also to move upon the knees (as carpenters, housemaids, and others), inflammation of this bursa is very frequently met with. In many instances it occasions little general or local disturbance, merely causing an increased effusion of the proper synovial secretion, without producing any change whatever in its natural properties. In other cases the fluid is not only increased in quantity, but becomes changed likewise in quality; it assumes the appearance of a turbid serum, with numerous flakes of lymph floating in it; or where the disease has been of long standing, the fluid is frequently found loaded with a number of loose bodies, almost of the consistence of cartilage, and of a flattened oval form. Sir Benjamin Brodie compares their appearance not inaptly to that of melon-seeds, and he considers them as portions of lymph originally of an irregular shape, but which, by the motions and pressure of the surrounding parts, have had their angles worn off, and assumed by degrees a firm consistence. They have been found likewise in the smaller bursæ. Monro has seen upwards of fifty extracted from the small bursa of the flexor pollicis longus tendon, where, by excessively distending the surrounding parts, they had produced severe pain. When the great vaginal bursæ of the flexor tendons have become the seat of effusion, a very remarkable appearance may present itself, at once explicable, however, by referring to the anatomy of the part. The fluid can by pressure be forced downwards under the annular ligament, and into the palm of the hand, and thence upwards again into the forearm. Some authors have deemed it proper to designate by a particular name this termination of the disease by effusion, and the words *thygroma* and *ganglion* have been applied with a good deal of confusion by different persons; but it appears to us that there exists no necessity for a specific name to refer to this accidental mode in which inflammation terminates.

A much more important termination of the disease is that in which, owing to local or constitutional causes above alluded to, the inflammation, having run a severer course, ends in suppuration. Sir Benjamin Brodie has in this case observed that the matter may take either of two courses: it may come directly to the surface; or, without pointing forwards, it may penetrate the side of the sac, and so become extensively diffused through the surrounding cellular membrane, involving the whole anterior and lateral portions of the joint. In such a case the practitioner is very liable to be deceived as to the true character of the abscess, and to confound it with those which originate in the cellular membrane.

There are certain cases in which acute inflammation of a bursa becomes even a more serious disease than that just alluded to. In the synovial sheaths of the flexor tendons, for example, the progress and termination of the inflammation are often modified in a remarkable manner by the anatomical peculiarities of that part. In that form of the paronychia affecting the anterior part of the finger, and seated in the synovial sheath of its flexor tendon, the inflamed membrane is closely bound down by a dense and unyielding fibrous layer: hence not only death of the contained tendon may be produced, but even extension of the disease to the bone itself.

Such are the morbid changes usually met with in the contents of inflamed bursæ; but if the disease have been of long standing, changes scarcely less remarkable are produced in the structure of the bursa itself. Instead of the delicate synovial membrane we have above described, it is frequently found converted into a firm gristly substance, sometimes half an inch in thickness. In such cases no tact, however delicate and experienced, could, previously to operation, have detected the presence of matter.

Monro seems to regard, in certain cases at least, the communication above alluded to between certain bursæ and the neighbouring joints as the result of rupture or of friction: he even considers it remarkable that in such instances neither lameness nor pain had been complained of during the lifetime of the individual. It appears to us, however, much more probable that in those instances the synovial membrane of the joint and that of the bursa have been *ab initio* but different parts of one and the same structure; at least, in our dissections of the subcrureus bursa in young subjects, we have more than once observed it communicating freely with the joint.

For Bibliography, see that of SYNOVIAL MEMBRANE.

(John E. Brenan.)

CARNIVORA *(caro, carnis,* and *voro,)* an interesting and highly important group of the mammifera, constituting the typical order of that great division of the class which feed upon animal aliment. Whether the present group can with propriety be considered as entitled by its organization to the ordinal rank which we have assigned to it above, or whether it does not rather form a subdivision of a great order, answering nearly to the *Carnassiers* of Cuvier, is a question which, as it is variously viewed by different naturalists, may be safely left undecided in a work like the present, in which structure rather than arrangement is the principal object of research, and in which the nomenclature of a system is of little importance, compared with the developement of anatomical and physiological truth. The *Carnassiers* of Cuvier (excluding the *Marsupiata,* which may unhesitatingly be considered as a distinct order,) includes a natural and tolerably well defined assemblage of animals, to which the term ZOOPHAGA may with propriety be applied as the classical equivalent to the French phrase of that distinguished zoologist; but however the stricter rules of zoological arrangement may render it difficult to divide this group into the three orders of CHEIROPTERA, INSECTIVORA, and CARNIVORA, it has appeared to the author of this essay as more convenient on the present occasion to assign that designation to each of these divisions, and to make the structure of each the subject of a separate article.

The characters of the Carnivora as distinct from the rest of the digitate animals possessing the three distinct classes of teeth, (which, besides the other *Zoophaga,* include the *Quadrumana* and the *Marsupiata,)* are such as point them out as especially formed for the pursuit and destruction of vertebrate animals. They possess in the upper and in the lower jaw six incisive teeth, a large, strong, and pointed canine tooth on each side, and molar teeth which partake in a greater or less degree of the characters distinctive of the class, according to the habits of the different genera. These molars consist of three distinct kinds: the anterior, which immediately follow the canine, are more or less pointed, and are termed false molars; the next class, formed especially for cutting in pieces the flesh on which the animals feed, are termed by M. Frederick Cuvier *Carnassiers;* and the posterior are tuberculated. The proportion which these different classes of teeth bear to each other in number or developement, accords with the degree of the carnivorous propensity in the animal.

In agreement with these characters of the teeth, the feet are digitate, the toes furnished with claws, which in some are retractile; the stomach is simple, the intestines are short, and the cœcum is either very small or altogether wanting.

The animals of this order differ in the form and position of the posterior feet; in some, hence termed plantigrade, the whole foot rests on the ground; in others, called digitigrade, the toes only touch the ground, the heel being considerably raised. Of the former structure the bears exhibit the type, and the cats of the latter. A third and most remarkable form of the extremities is shown in the Seal tribe, in which the anterior as well as the posterior feet are formed for swimming, being spread into fin-like paddles.

The families of which this order is composed are perhaps as follow:—

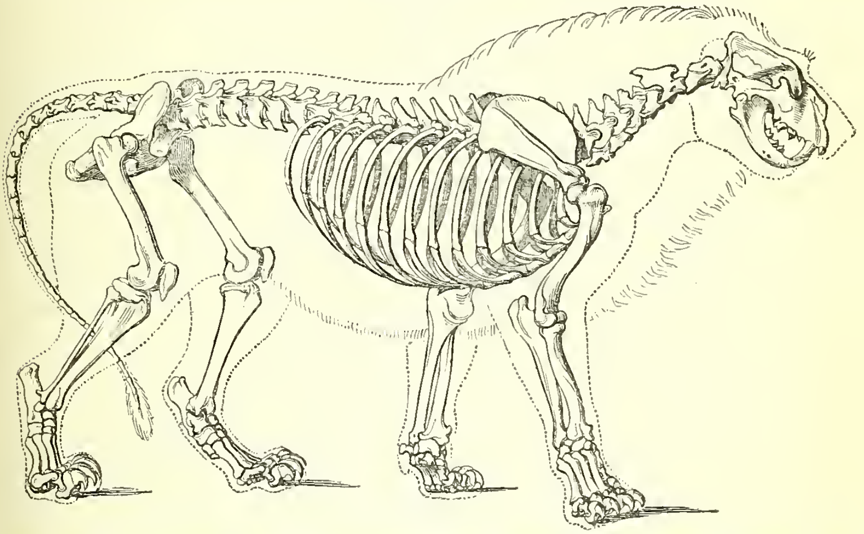
1. URSIDÆ,	typical genus	*Ursus,*	bear.
2. MUSTELIDÆ,	do.	*Mustela,*	marten.
3. CANIDÆ,	do.	*Canis,*	dog, wolf.
4. FELIDÆ,	do.	*Felis,*	cat.
5. PHOCIDÆ,	do.	*Phoca,*	seal.

Of these families the FELIDÆ constitute the type of the order, possessing the carnivorous propensity and structure in a higher degree than any of the others.

Skeleton.—The structure of the skeleton in the cat tribe exhibits, in the greatest imaginable degree, all the requisites of fleetness, activity, and power, for the purpose of pursuing, surprising, overpowering, and tearing the living prey on which, in a state of nature, they wholly subsist. In the less typical forms we find these attributes possessed to a modified extent, but still admirably adapted to their respective habits.

As an example of the typical structure, the skeleton of the lion (*fig.* 189) shews, in the configuration of the bones, in their articulation, and in the developement of the different points of muscular attachment, such a combination of lightness of form with vast power, as must strike every one as being exactly equivalent to the natural requirements of the animal. The spine is flexile, yet of great strength, and the extent and robustness of the lumbar portion of the vertebral column seem at once adapted for the exercise of that flexibility, and for the location of powerful muscles. The ribs are narrow and far asunder; the limbs long, powerful, and so constructed as to afford the greatest facility and extent of motion, an object which is greatly promoted by placing the point of rest at the extremity of the toes; the whole of the feet, excepting that part, being thus made subservient to the object in question. The cranium is broad and short, and fitted for the exercise of almost incalculable force in holding and tearing their food.

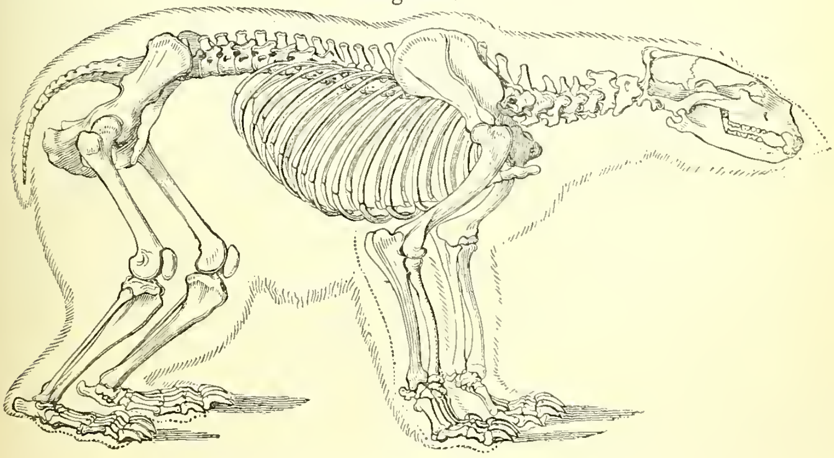
Fig. 189.



In the weasel tribe the legs are shorter, the vertebral column elongated and in the highest degree slender and flexible, the lumbar region being as long even as the dorsal, a structure by which they are enabled to creep with almost a serpentine motion in quest of the small and sometimes subterraneous animals on which they subsist.

In the bear tribe (*fig.* 190) there is a still

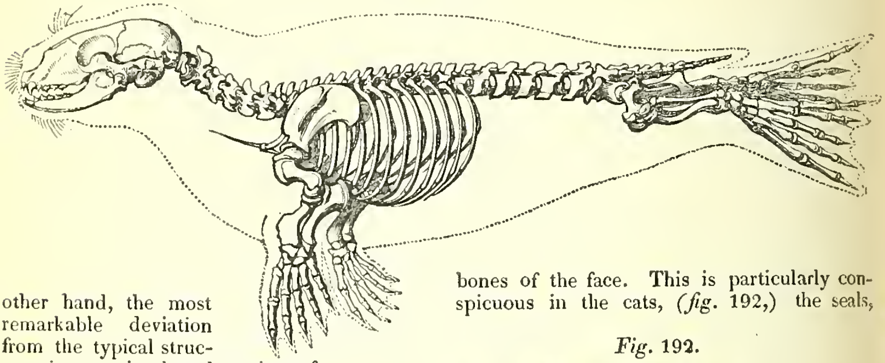
Fig. 190.



greater aberration from the type, in the plantigrade form of the foot, by which the animal is enabled to walk with that solidity and firmness which the less degree of mobility in the rest of the skeleton renders necessary, or to climb trees, or dig the ground, in pursuit of the various food from which the different genera of this family derive their nutriment. The small extent of the lumbar portion of the spine compared with the dorsal which we find in some of this tribe, is equally characteristic.

In the Phocidæ or Seals, (*fig.* 191), on the other hand, the most remarkable deviation from the typical structure is seen in the adaptation of the limbs to the aquatic residence and habits of the animals. The posterior members are extended backwards in a horizontal direction, forming two broad fins, by which they swim with great facility and strength. The anterior feet are similarly constructed, but they serve also in some measure for progression on land, though to a limited extent. The cranium is thin and round, and the teeth, sharp and many-pointed, are formed for seizing, holding, and tearing fish, the activity of whose motions, no less than their scaly surface and even, rounded form, render such a structure absolutely necessary.

Fig. 191.



The cranium.—The peculiarities by which the cranium of this order is distinguished have reference, not to the form and developement of the brain only, but particularly to the character of the food, and the consequent necessity of peculiar powers of mastication, and of the other acts preparatory to the function of digestion. We shall find, therefore, not only that the general form of the skull in the whole of the *Carnivora* is different from those of every other group, but that the families composing it differ in minor points of structure, with the same relation to aliment and habits. The cranium in this order then is characterized, when compared with that of most other orders, especially those which feed on grain or other substances requiring long and laborious trituration, by great shortening of the bones of the face. This is particularly conspicuous in the cats, (*fig.* 192,) the seals, (*fig.* 193,) and even the hyenas, but is less so in the bears (*fig.* 194) and dogs. The

Fig. 192.

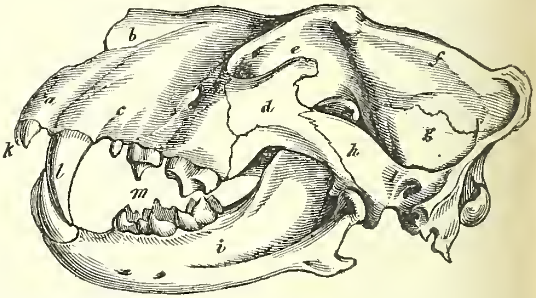


Fig. 193.

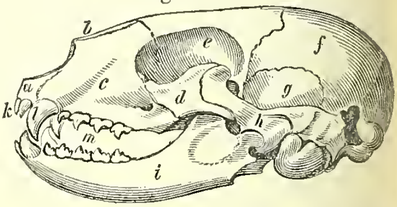
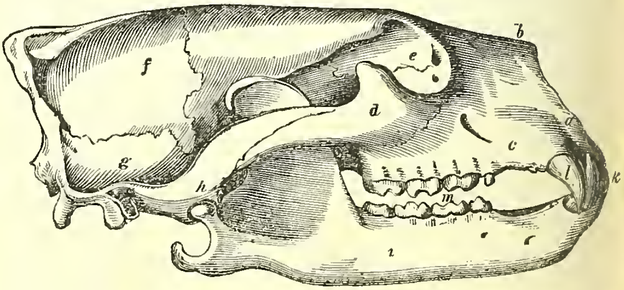


Fig. 194.



posterior aspect is generally small, directed backwards, and separated by a strong occipital crest from the anterior parts of the skull. From this, in many instances, a strong, elevated, median crest passes forwards, which is remarkably short in the lion, the white bear, the hyena, the badger, and many others. It is remarkable that in many of the Phocidæ this crest does not exist, whilst in other species it attains a considerable size. The orbit and the immense temporal fossa are confounded in one great excavation; the zygomatic arch is perfect and of considerable size. The anterior opening of the *nares* is large, and directed forwards, excepting in certain seals, in which it is placed almost vertically, for the obvious purpose of facilitating its exposure to the atmosphere when these animals come to the surface to breathe.

A remarkable peculiarity exists in this order, in the existence of a bony process arising from the internal surface of the occipital and parietal bones, and separating the lobes of the cerebrum from the cerebellum. This process, of moderate size in the dogs, is much larger in the seals, and still more developed in the cats. In the dogs it is considerable from before backwards, but small from side to side; it is formed by the parietal and the squamous portion of the occipital. In the seals the parietal bone is not concerned in its formation; in the cats, on the contrary, it entirely arises from this bone, not being at all connected with the occipital. The object of this bony tentorium is obviously to support the different portions of the brain, and prevent their pressing upon each other during the sudden and violent movements of the animal, when springing upon its prey or leaping with great violence.

With regard to the substance of the bones of the cranium in this order, although it may be observed generally that they are of a medium degree of thickness and solidity, there are remarkable exceptions in some of the seals, in which they exhibit an extreme degree of tenuity, the object of which, in reference to the medium in which the seals reside, and the necessity of often rising to the surface to breathe, is sufficiently obvious. In the cats and other genera, where extraordinary and sudden exertion is frequently necessary, the bones altogether are found to be remarkably compact and solid.

A few details of the structure of the individual bones composing the cranium will be necessary, in order to shew how admirably every portion is made to bear upon the general objects of the whole organization.

The *frontal bones*, (*fig*. 192, 193, 194, *e*,) which, as in most other instances, are separate, have a considerable developement of the zygomatic or external angular process, especially in those whose habits are preeminently carnivorous, as in the cats, the mustelidæ, &c. In the ichneumons it even extends so far as to meet the orbitary process of the malar bone, and thus form a complete orbitar circle; the cats exhibit an approach to such a formation, but in the other tribes it is less and less marked, and in the seals there is scarcely the vestige of this process to be perceived.

The *parietal bones* (*f*) are of a quadrate form; they are early united in the mustelæ, the cats, the hyenas, and the bears; in the dogs and in the seals, &c. they remain more durably separated. The interparietal bone, as it is called, (a large *os triquetrum*,) which is found in many animals, particularly during the young state, is considerable in the dogs, in which it remains permanently distinct from the parietal and occipital. Its form in these is that of an elongated triangle, which extends forwards, separating the two parietal bones for more than half their length. In this instance it proceeds from a single point of ossification, whilst in many of the *rodentia* it arises from two centres of developement. The crest which is formed along the median line of the cranium, at the junction of the parietal bones, and which forms a continuation forwards from the ridge of the occipital, is greatly developed in the older cats and others. The lion and tiger, the wolf and the bear, the badger and many others, exhibit it in an extraordinary degree. Its object is evidently to afford a strong and extended surface of attachment to the powerful temporal muscles, which are required to be enormously developed for the purpose of cutting and tearing in pieces the hard tendinous portions of the animal's prey.

The *temporal bone* (*g*) is divided, as in the other mammalia, into a cranial or squamous, and a petrous or acoustic bone. The former constitutes the posterior and superior portion of the zygomatic arch, and beneath the root of this process is situated the articular cavity for the reception of the condyle of the lower jaw. Its transverse form, and the depth of its anterior and posterior boundaries, afford a strong and secure hold of the condyle, which, whilst it thus moves freely within its limited sphere of action, is restricted from any other than a simple hinge-like motion. This circumstance adds greatly to the power of this particular kind of mastication. The squamous portion is but small, and is externally more or less convex. The acoustic portion is greatly developed in the cats, and still more so in the seals, a circumstance which will be further alluded to hereafter.

The *occipital bone* varies much in the carnivora. In the seals the superior or squamous portion is large, obtusely triangular, and much flattened, being in many species devoid of the strong occipital ridge which is so prominent a feature in all the other families of the order. In the cats this process is very prominent and strong, forming a solid attachment for those powerful muscles which are necessary for the forcible and even violent raising of the head in tearing the prey to pieces. It is also strongly marked in most of the *Ursidæ*, particularly in the white bear, the badger, the coati, &c. The inferior portion, answering to the cuneiform process, is in the seals remarkably broad and thin, much more so than in any other of the mammifera; and in this part there is in some species of that family an oval hole of considerable size, placed near the inferior margin of the *foramen magnum*. This exists only in certain species, in *Ph. vitulina* for instance, and appears to harmonize with the tendency to scanty deposition of bony matter, which characterizes the whole cranium in this family. The condyles in these animals are also very much larger than in the other carnivora.

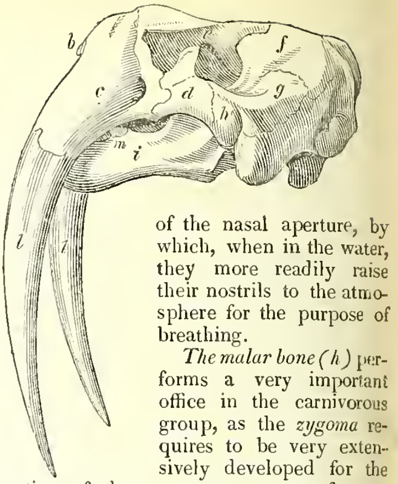
The sphenoid bone has nothing very remarkable in its structure, excepting the greater developement of its alæ in these than in most others of the mammalia, and the small compressed triangular form of the pterygoid processes which in the cats are long and hooked backwards.

The superior maxillary bone consists of the true or posterior maxillary *(c)* and the intermaxillary *(a)* portions. For the sake of clearness they may be described as distinct bones. The body of the maxillary bone extends very high up in the cats, and is remarkably strong and *compact*. In the seals it is encroached upon by the nasal opening, so as to leave only a narrow neck between that opening and the orbit. The *infra-orbitar foramen* is remarkably large in the cats and in the seals, in which animals the long elastic setaceous whiskers are so useful as feelers, and are supplied with large filaments of the infra-orbitary branch of the fifth pair of nerves. The length of the body of this bone depends on the number and nature of the teeth which are imbedded in it, and is shorter in proportion to the predominance of the strictly carnivorous appetite. The *canine teeth* and the *molares* are those which occupy this bone, the *incisores* being placed in the intermaxillary; and in the cats the body of the bone is remarkably short, being occupied only by four molar teeth, the first of which is small and rudimentary, as well as the posterior one, which is small and tubercular; the two middle ones are formed for cutting asunder the flesh, and are exceedingly strong. In the bears the teeth assume more of a tubercular form, and are, in fact, adapted for masticating vegetable substances as well as animal matters; the jaw-bone is, therefore, much longer than in the cats. In the dogs, which hold an intermediate place in this respect, the molar teeth are six in number, and the two posterior ones are more or less tubercular. The anterior part of the jaw is enlarged and rounded for the location of the large and powerful canine teeth. In the *Walrus* (*fig.* 195,) the anterior part of this bone is greatly enlarged for the enormous canine teeth, which form powerful weapons, with which the animal strikes directly down with immense force.

The *intermaxillary bones* contain each three small incisor teeth: these in the cats are very small, excepting the external one, which is somewhat larger than the others. In the seals they are pointed. These bones are considerably smaller in the *carnivora* than in most other orders.

The *nasal bones (b)* are smaller in this order than in many others. In the cats they are rather broad anteriorly, but short; they are longer in the dogs and bears, agreeably to the greater length of the face generally. In the seals they are much shortened, in order to allow of the great expansion, in an upward direction, of the nasal aperture, by which, when in the water, they more readily raise their nostrils to the atmosphere for the purpose of breathing.

Fig. 195.



The malar bone (h) performs a very important office in the carnivorous group, as the *zygoma* requires to be very extensively developed for the protection of the enormous masses of muscle which are needed in tearing the food of these animals, as well as for the attachment of the *masseter*. The zygomatic arch in this order is convex upwards as well as curved outwards, by which form a great increase of strength is acquired in the direction of the muscular force.

The *lacrymal bone* is said to be wanting in the seals. I believe I have seen a trace of its existence in a rather young cranium of *Phoca vitulina*. The remarkable vacancy which occurs in some of this tribe in the orbito-temporal fossa, between the frontal, the maxillary, and the sphenoid bones, has been supposed by Meckel to indicate the place which the lacrymal bone should occupy; but as this hiatus does not exist in several species, in which the absence of this bone is equally evident, this supposition is probably not correct.

The inferior maxillary bone (i) follows of course the general structure of the superior. It is remarkably short in the typical forms of the *carnivora*, and more elongated in the others, particularly in the bears. Indeed this bone, like the upper jaw, is shortened exactly in proportion to the carnivorous propensity of the animal. The ascending plate is also remarkably developed, and offers a surface of great extent for the insertion of the elevators of the lower jaw.

The character of the *vertebral column* in the *Carnivora* offers some interesting varieties of form, depending principally on the degree of exertion, of activity, or of flexibility required by the habits of the different genera. The strength and size of the two first cervical vertebræ, the *atlas* and *dentata* or *axis*, have already been alluded to. The first is exceedingly broad and robust, with strong transverse processes; the second is long, with an enormous spinous process. The remainder of the *cervical vertebræ* are generally rather elongated in most of the genera, but in the seals they are short and but little developed. In general, also, the spinous processes are considerable, and either perpendicular or directed rather forwards, particularly in the cats, the coatis, the badger, and some others. In the dogs there are also small inferior spinous processes. The dorsal region varies much in its relative proportions with the lumbar region and with the size of the animal; a point which will be more particularly alluded to presently. The spinous processes are very strong and strait, and directed backwards. The number of the *dorsal vertebræ*, and, consequently, of the ribs, varies in the different genera of the order, from thirteen, which is the most common number, to sixteen, of which we have an example in the Glutton (Gulo articus).

The *lumbar vertebræ* are remarkably strong in almost all the *Carnivora*, though less so than in some other orders. The spinous processes are long and directed forwards, particularly in the cats and dogs. The transverse processes are also very large and strong; but the most important circumstance connected with the character of these vertebræ is the relative proportions which exist between them and the dorsal in different species, not so much with regard to number, as to the proportional extent of the two regions. In respect even to number, the variations of the lumbar vertebræ are not inconsiderable: thus, the Ratel and the Hyena have only four, whilst the cats and many others have seven. But we find that in those species which, from their habits, require great power of springing, of rapid running, or of great flexibility of motion, the relative extent of the lumbar region is increased in proportion. Thus, whilst in the Hyena the lumbar region bears to the dorsal only the proportional length of four and a half to fourteen, and in the Ratel of three to eight and a half; in the Lion we find it as fifteen to eighteen, and in the Panther, the Wild Cat and the Civet, the extent of the two regions is almost exactly equal. This is a consideration of great importance, not in the *Carnivora* only, but in the *Ruminantia* and other orders, where the different groups are found to vary much in their powers of springing and their general activity: for the proportion of the lumbar to the dorsal regions will invariably be found in exact accordance with the extent of those powers.

The Sacrum is composed of several vertebræ, as in most other *mammifera;* in the present order there are generally three or four, though in the Brown Bear there are six (Cuvier says five), and in the White Bear seven; in the Coati there is but one, and in the Hyena only two. The spinous processes of the Sacrum are more developed in this order than in many others. Cuvier observes that, in those animals which, from their habits, occasionally rise upon their hinder legs and hold themselves upright, the Sacrum is broader than in others of the same order, and he instances the Brown Bear in the present order as an example.

The tail, consisting of the *coccygeal vertebræ*, varies excessively amongst the *Carnivora*, and this in many cases in the same family, and with but little obvious relation to the habits of the species. As a general rule it may be observed that the most active, and those which possess the most flexible spinal column, have the greatest number of caudal vertebræ. Thus, while the Brown Bear has only about six, the Lion has twenty-three, and the Panther twenty-four.

In many of the *Carnivora* which have long tails, the spinous processes are generally directed from before backwards, but are always very small, and exist only on the few anterior vertebræ of the tail. The middle and posterior *coccygeal vertebræ* are therefore more developed in length and become almost cylindrical, excepting that they are thicker at each extremity. As in other orders, the anterior portion only of the tail conveys the spinal marrow, the posterior being impervious. The most imperfect developement of this portion of the vertebral column is found in the Seals, in which generally it is only the first vertebra which possesses even a trace of spinous and transverse processes, the remainder being almost cylindrical, without even any enlargement at each extremity.

The ribs correspond in number with the dorsal vertebræ. Their curvature varies considerably both as regards the different portions in the same species and the general form in different groups. In many of the *mammifera* the difference in this respect between the anterior and middle regions of the thorax is very striking; this, however, is generally not so much so in the present order, in which, as a general rule, the anterior ribs are not less arched than the others. The anterior ones, however, are very much smaller and shorter than the middle and posterior. The relative number of true and false ribs would, à priori, appear to have some relation to the degree of rapidity or of flexibility in the animal's movements; and hence that those which leap or swim would require greater mobility of the thorax, and consequently a greater proportion of false ribs. Now, although this is strikingly the case with regard to some of the *cetacea*, which have only from one to five fixed ribs, and from ten to seventeen false, yet no such rule is observable in the present order; the Seal and the Lion having even a less proportion of moveable ribs than the Bear and the Glutton.

The sternum in the Carnivora does not vary greatly in breadth in its different portions. It is much more developed longitudinally in these animals than in most others, and is scarcely broader than it is deep. The anterior piece of this bone in the Seals is remarkably long, and is also moveable.

The shoulder, composed of the same elements as in the other *mammifera*, varies, however, considerably in the degree of developement of the bones of which it is formed. *The scapula* is depressed and remarkably broad from the anterior to the posterior margin, and in some cases—as in the Badger especially, and in some degree in the Bear—it assumes almost a quadrate form. The spine of this bone, which in the Seal is very small, is of great size and strength in the bear tribe, particularly in the Badger. The *acromion* is small and slight in all the true *Carnivora*, but in those of the *Insectivora* which have true clavicles, it is long and robust. The *coracoid process* is generally present, but is wanting in the seals. *The clavicle* in the whole of this order is very slender, and must be considered as merely rudimentary. In the *Hyena* and the Dog it is extremely small; larger in the *Mustelidæ*, and still larger in the Cats. It is not attached to the *sternum* or to the *scapula*, but suspended, as it were, between these two bones, generally occupying not much more than half the space between them.

The humerus is in general rather slender, long and nearly cylindrical when compared with that of the *Pachydermata*, *Ruminantia*, and some others. It is somewhat arched, and the great tuberosity is very much developed; this bone is short and broad, the superior two-thirds being widened from before backwards, and the lower third from side to side.

The *fore-arm* is here, as in the other orders, composed of the *radius* and the *ulna*. The latter bone is generally placed immediately behind the former, and they have but little motion one on the other, excepting in the bear tribe, whose habits require more freedom of movement in the anterior extremity. That tendency to the expansion of the members into instruments fitted for swimming, which is so obvious in the Seals, is found to obtain in the two bones in question, which in this family are short, flattened, and very broad.

The *carpus* in this order offers a few peculiarities which may be slightly glanced at. The *os scaphoïdes* and the *os similunare* form but one bone, which is of considerable size. The *os pisiforme* is much elongated, forming a little spur or heel to the anterior feet, a peculiarity, however, which is wanting in the seals. The *os trapezium* is very small in the *Hyena*, in which the thumb is but rudimentary.

The *metacarpal bones* in the digitigrade carnivora are much larger than in the plantigrade. In the latter the shortness of these bones, with the comparative length of the *phalanges*, gives somewhat of a plantigrade character even to the fore-feet, although the metacarpal bones do not actually rest upon the ground: whilst in the digitigrade families, and especially in the cats, the metacarpals being much produced, and the phalanges very short, the part which rests upon the ground is greatly abbreviated.

The *phalanges* offer some very interesting points of structure, particularly in the *Felidæ*, in which the terminal phalanx is retractile, or, on the other hand, can be thrust out and rendered the basis of a most formidable weapon. This character of the retractile claw is, in its full developement, peculiar to the family just named; and the Lion may be selected as offering, from its great size, the most convenient opportunity for its examination. In all the Carnivora the claw is fixed on the extremity of the last phalanx (*fig.* 196, *a*, *a*), the hooked form of this part of the bone being an accurate model of the interior of the claw, and the base of the claw is secured within a thin lamina or hood of bone which covers it on the sides and above. In the animal just named this is particularly strong and large. It is considerable also in the Badger, but less so in the Bears, the Dogs, the Hyenas, &c., and in the Civets it is very small. The *penultimate phalanx* is of a peculiar form. Its transverse section would be triangular, two of the sides being lateral, and the third inferior. On the inner face or side, there is a hollowing or twist of the bone, which leaves an oblique excavation in the middle. It is by the inferior portion of the last phalanx that it is articulated to the penultimate, and beneath the joint a process of the last phalanx extends downwards, for the attachment of the muscles by which the toes are flexed, and consequently the claw protruded. When the claw is retracted or in a state of rest, the last phalanx is brought upwards and thrown completely back on the inner side of the second phalanx, being partly lodged in the lateral hollow before described. This is the condition of repose, and the last phalanx is held in this situation by the elasticity of the capsular ligament, and particularly by two lateral ligaments which arise from the second phalanx.

The posterior extremity.—The *pelvis* in the *Carnivora* is shorter than in many other orders, and the *ossa ilii* particularly are flattened and rather broad. Their internal surface also is not turned forwards as in most other orders, but for the most part directed towards the spine, so that the ventral aspects of these two bones face each other. In most of the seals the ilia are short and small, compared with the other bones of the pelvis. The posterior or descending branch of the *ischium*, and the anterior portion of the *pubis* are, in particular, much elongated in this family.

The femur is strait, cylindrical, and moderately long in most of the *Carnivora*. In the Seals it is, however, extremely short, as may be observed in *fig.* 191. In this tribe this bone does not assume the direct backward direction of the leg-bones, but stands outwards and downwards, by which a great extent of motion is obtained for the hinder paddles.

The tibia and fibula,* (*fig.* 196, *l*, *m*; *fig.* 197, *i*, *k*; *fig.* 198, *l*, *m*;) are detached in most of the Carnivora; but in the Dog the *fibula* is attached to the back part of the tibia. In the *Phocidæ* these bones are long, flattened, directed backwards, and the tibia has a double curvature. The tarsus consists of the same bones in the Carnivora as in Man, (*fig.* 196, *f*, *g*, *h*, *i*, *k*, *fig.* 197, *e*, *f*, *g*, *h*, *fig.* 198, *f*, *g*, *h*, *k*,) the os calcis has a very long and robust tuberosity both in the digitigrade (*fig.* 196, *k*) and plantigrade (*fig.* 197, *h*) forms. In the former there is also on the inferior surface a small tubercle which is wanting in the others.

* The figures representing the hinder foot are selected for the purpose of shewing the three principal types of progression in the Carnivora. *Fig.* 196, that of the Lion, exhibits the digitigrade, *fig.* 197, that of the polar bear, the plantigrade; and *fig.* 198, that of the seal (*Phoca vitulina*), the natatory.

Fig. 196.

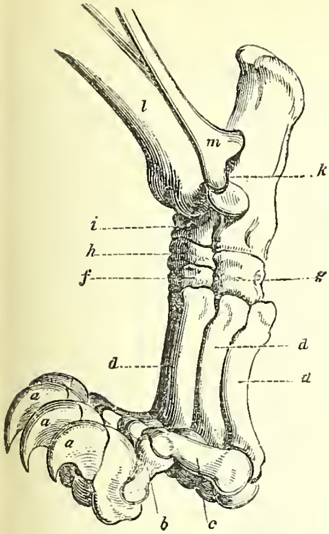


Fig. 197.

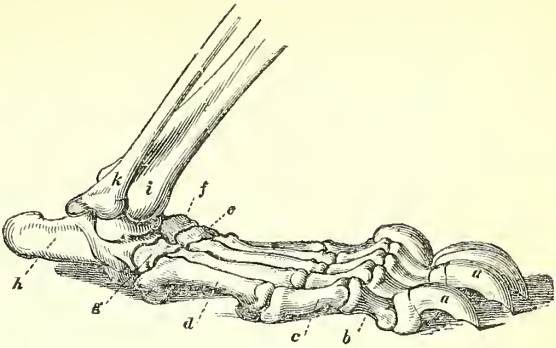
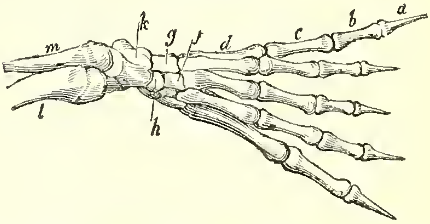


Fig. 198.



The metatarsal bones (*fig.* 196, 197, 198, *d*) are generally five. In the cats and the dogs, indeed, the inner one is merely rudimentary, a defect which is perfectly consonant with the absence of a posterior thumb in these two genera. Those of the seal tribe are remarkably long and slender. The first is the longest, the fifth the next, then the second, the fourth, and the middle one which is the shortest.

The toes consist of three *phalanges* (*fig.* 196, 197, 198, *a*, *b*, *c*,) and in most genera there are five toes; the bears and other plantigrades having the inner toe or thumb in the same range as the others; in the *mustelidæ* it is a little smaller, and in the cats and dogs it is wholly wanting. The toes in the seal tribe are developed to considerable length, and being much extended, and covered with an entire skin which extends from one to the other, a very perfect finlike paddle is thus furnished.

The types, then, of the three different varieties of progression are here distinctly shewn. In the foot of the bear (*fig.* 197) we find that every thing in its formation is made subservient to the action of walking; the heel, the tarsal and the metatarsal bones, and the phalanges all rest upon the ground, and these bones are elongated for that purpose. In the Lion (*fig.* 196) the last phalanges only rest on the ground, the heel being drawn upwards, and the whole of the foot, excepting that small portion which is applied to the ground, is thus made an additional lever for the increase of the animal's powers of leaping and bounding in its course. In this form the limb consists of three joints (the pelvis being the fixed point) moveable in alternately different directions, capable of being all approximated to each other, and then suddenly and simultaneously extended with prodigious force. In the third type, that of the Seal (*fig.* 198), the bones are all much flattened, and, excepting the foot, greatly shortened; the foot itself being developed both longitudinally and laterally into a finlike expansion.

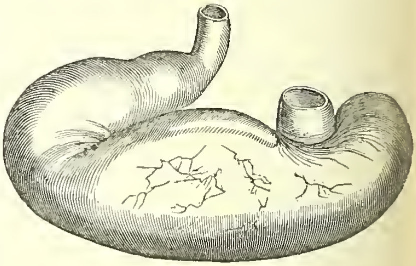
The Muscular System.—The general character of the muscles in the *Carnivora* is that of combined power and irritability. The elevators of the lower jaw, the *masseters* and the *temporals*, are enormously large, for the purpose of cutting and tearing the flesh and the harder portions of their food. The muscles of the face also, those of the lips, of the nose, of the eyelids, and of the ears, are all of them greatly developed and capable of the most extensive and powerful motion. A moment's reflexion upon the habits of these animals, and particularly on those of the cats, will shew the necessity of enormous power in the muscles which raise the head upon the spine. A Lion, it is said, can kill a moderate-sized bullock, throw it on his back by a toss of the head, and trot off with it to his hiding-place. All the muscles, therefore, which arise from the vertebræ of the neck and are inserted into the projecting ridge of the occipital bone, are of prodigious strength. The same remark holds good of all the muscles of the limbs, particularly those of the anterior extremity, but which do not require a particular description or demonstration. The muscles of the tail, which are for the most part similar in this order to those in the tailed *Quadramana* and *Ruminantia*, will be described in the articles devoted to the anatomy of those animals.

The digestive organs.—The structure which has been already detailed in the skeleton of the Carnivora, and alluded to in their muscular system, will be found altogether subservient to the office of procuring that peculiar kind of food to which these animals are restricted, and the modifications of that structure which have been described as appertaining to different types of form in the order, are equally consonant with the modified nature of their aliment. Thus, whilst the powerful yet active and flexible movements of the typical *Carnivora* are adapted only to the pursuit and destruction of living prey, the more sluggish habits of most of the bear tribe, their peculiar mode of progression, and the modified structure of the skull, the teeth, and the limbs, are all equally applicable to the mixed nature of their food; and the third principal type—that of the *amphibious carnivora*, the Seals—exhibits an arrangement of these organs not less admirably fitted for the pursuit and capture of their aquatic and scaly prey. The digestive organs of each of these prominent groups are not less perfectly formed for the digestion of their various food, than the organs which have already been described are for its capture. The teeth have already been slightly alluded to, but they deserve a more particular description. In the cats, the character of the teeth is typically carnivorous. The *incisores* are very small, as indeed they are throughout the whole order. The *canine teeth* are, on the contrary, pre-eminently strong, long and sharp, and are evidently adapted for seizing and holding their prey and afterwards tearing in pieces the flesh and other soft parts of the animals. These teeth are conical and very slightly curved, a form which, united with their sharpness and strength, is the best that can be imagined for effecting this object. The cheek teeth, instead of having flat grinding surfaces, have, for the most part, only cutting edges; and those of the lower jaw shut within the upper, passing them so closely as to form an accurate instrument either for shearing off pieces from the flesh or for cutting into morsels the portions which have been torn by the canine teeth. On each of them are sharp triangular processes which much facilitate the entrance of the tooth into the flesh. The range of these teeth is short, as is also the whole jaw, by which great power is gained in this particular direction. The articulation of the lower jaw is also circumscribed to a perpendicular motion, the only one which the structure of the teeth would permit. The strong muscles of the lips also enable the animal to raise them out of the way of injury during this process. The animals of the bear tribe, on the other hand, have an elongated jaw, canine teeth, although very large and strong, yet less so than in the cats, and molares, the surfaces of which, instead of being raised into cutting edges, are depressed, tubercular, and require a certain degree of lateral motion in the jaw to bring them into action. In the seals a very different structure of the teeth is observed. The canines are not particularly large and prominent; and the molares, neither adapted on the one hand for shearing nor on the other for grinding their food, either of which actions would be unavailable in their particular case, are numerous and furnished with several angular points, which are fitted for holding the slippery, scaly surface of fish, and equally so for crushing them before they are swallowed. The teeth of the Walruses, however, are very different from those of many other of the *Phocidæ*. The tusks (*fig.* 195) which are enormous canine teeth of the upper jaw, are directed downwards, and constitute formidable weapons of defence, and the molares are formed rather for grinding than for merely holding their prey.

The food then being thus variously prepared by the different groups of this order, passes into the stomach more or less masticated. The salivary glands in the meantime have been performing their important office. The variations in form and situation of these glands are slight and unimportant. The submaxillary glands are generally as large as the parotid, which in the dogs and cats are of a crescentic form, embracing by their concave margin the conch of the ear; and in the dogs the inferior portion is distinct from the rest. The sublingual are wanting in the cats.

The stomach in all the animals of this order is perfectly simple, and its interior smooth, with the exception of that of the Seal, which has a villous coat. In the cats (that of the Lion is shewn at *fig.* 199) it is elongated, and

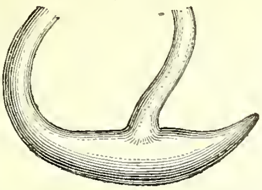
Fig. 199.



the two openings are placed nearly at each end: there is a small pouch however at the cardiac extremity. In the Wild Cat it is somewhat pyriform, the pyloric portion being, as in the Lion, doubled upon the other part; and in the Lynx the cardiac and pyloric openings are more distant than perhaps in any other species. In the other genera the form varies a little. It is nearly globular in the Racoon; that of the Hyena is large and short. In the seals it is elongated from before backwards, the pyloric portion being turned forwards upon the other; at the bend there is a pouch, at which point a glandular layer is found between the internal coat and the cellular.

The intestinal canal is in these animals remarkably short, particularly in the cats; in the Lion and in the Wild Cat the whole alimentary canal is but three times the length of the body. In the Seal it is much longer. The distinction between the small and large intestines varies considerably. In the Badger this distinction can scarcely be said to exist: in the Lion it is considerable, and still more so in the seals and others. The *cæcum* exists, but is very small and short in the cats: (*fig.* 200 shews that of the Lion.) In the dogs it is spiral. The whole canal is almost destitute of *valvulæ conniventes*, nor is the large intestine tucked up into sacs as in other orders. The *mustelidæ* generally have no *cæcum* nor *valvulu coli.*

Fig. 200.



A short comparative view of the structure thus hastily sketched, with that of the digestive system in the typical *herbivora*, the ruminant animals, will not be uninteresting. The Carnivora feeding on aliment which requires but little elaboration to convert it into nourishment, the whole process of digestion appears to be as rapid as possible, and we find that every part of the organisation is admirably adapted to this object. The strength of the jaws, the form of the teeth, the structure of the maxillary articulation are all contrived for preparing the food by simple division. The stomach is simple and almost straight, the intestines short, and without any structure to retard the passage of the food. In the *ruminantia*, on the contrary, the jaws are much elongated, the molar teeth flat and formed for affording the greatest possible extent of triturating surface, the maxillary joint allowing of the most extensive lateral motion, the stomach complicated, and a second and more complete mastication is performed after the food has been long macerated in the paunch. The intestines are exceedingly long, (in the ram twenty-eight times the length of the body,) very large, and tucked up into folds and sacs throughout their whole length. Here every thing is arranged for the thorough comminution and maceration of the food, and for the greatest possible retardation of its passage through the body, as well as for an immense extent of absorbing surface for the extraction of every particle of nutritious matter.

The liver in the Carnivora is deeply divided into lobes, which vary in number in different species. Thus in many of the plantigrades there are five, as the brown bear, the coati, and the racoon; in the otter also, and in the martens and generally in the dogs there are the same number. The Badger has but four. The cats generally have from five to seven, though that of the jaguar has but four, and that of the lynx eight. This numerical variation appears, therefore, to have no reference to any physiological law, nor to any peculiarity of habit.

The hepatic ducts offer some peculiarities worthy of notice. In the cats there are always several, which correspond with the different lobes of the liver. Before the *ductus communis* opens into the *duodenum* after passing the muscular coat of the intestine, it forms a considerable enlargement, divided by an internal contraction into two cavities, into the first of which the pancreatic duct opens. In the dog the *dactus communis* enters the intestine with *one* of the pancreatic ducts. In the otter, the common duct forms a second reservoir near the duodenum.

The *gall-bladder* exists in all the Carnivora. It varies in some measure in form, being pyriform in most, elongated and almost cylindrical in many of the *mustelidæ*, and rounded in the bear, the racoon, and some others. It is of great size in several of the plantigrades.

The pancreas is similar in its general structure to that of the other *mammifera*. It varies in form, but not in any way that can be supposed to give it a peculiarity in function. The pancreatic ducts vary also in number and in the situation at which they open into the liver. In some instances, as in the cats, the pancreatic and common biliary ducts are united and enter the intestine at one orifice, though this circumstance is not uniform in the genus, nor even in all individuals of the same species. As a general rule in this order the ducts of these two important glands terminate together.

The spleen requires also to be merely glanced at, as its characters and situation do not materially differ from those in the other orders of the class. It is generally elongated and narrow, and either flattened or somewhat prismatic.

The chyliferous system.—The chyle in the *Carnivora* has always been remarked for its whiteness and opacity, a circumstance which greatly facilitates the tracing the course of the lacteals in this order, and which in fact gave rise to their discovery in these animals before they were seen in man. *The mesenteric glands* are united either into one large mass only, as in most examples of the order, into two as in *mustela*, or the larger substance is associated with several smaller ones, as in the cats, the otter, the seal, and some others. This glandular mass has been termed *Pancreas Asellii*, from its having been erroneously mistaken for a pancreas by that anatomist.

The thoracic duct in the dog is double, and in the Sea Otter it has been found by Sir Everard Home that two ducts go from the *receptaculum chyli* to form this duct, which in its course sometimes divides into two, three, or four, again uniting at intervals.

Organs of circulation.—*The heart and blood-vessels* offer but few peculiarities in this order worthy of particular notice. The heart varies but little in form; its parietes are remarkably strong in the larger cats, in the lion particularly. The general structure of this viscus does not differ materially from that of the other mammifera. There is, however, a question of some interest which has been often debated; this is, whether the *foramen ovale* and the *ductus arteriosus* remain pervious in the seals and the otter. The testimony of Cuvier and of Blumenbach goes to prove that, at least in many instances, these openings are closed. Cuvier states it to have been so in a seal, and Blumenbach says that this is its general condition. On the other hand Sir Everard Home has given two examples in which the *foramen ovale* remained pervious in the sea otter; Blumenbach also states that he possesses the heart of an adult seal, in which both these channels of communication remained open; and the writer of this article dissected a seal some years since which was nearly full grown, in which the *foramen ovale* was so open as to allow the tip of the little finger to enter, and the *dactus arteriosus* would admit with ease the bulb of a common probe.

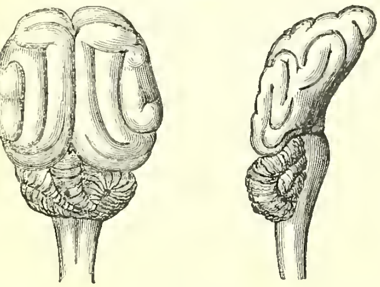
Upon the whole then it appears that, although the pervious condition of these channels cannot be considered as general in the adult state of these diving animals, as has sometimes been supposed, it must be allowed that this exception is far more frequent in them than in any other mammiferous animals, and that, as a general rule, these holes remain open later in such animals than in others. There is, however, in the otters and in the seals, a considerable dilatable enlargement observed in the *inferior cava*, which serves doubtless as a reservoir to retain part of the returning blood during submersion, until the animal rises again to breathe.

Organs of respiration.—The langs are divided into lobes varying but little in number in the terrestrial families of the order. These all have four lobes to the right lung, and either two or three to the left. The seals have the right lung divided into two lobes, and the left undivided.

The cartilaginous portions of the rings of which the *trachea* is composed vary in the proportions which these bear to the whole circle; in the genus *Mastela* and some others, the cartilage forms about two-thirds of the circle; in the bear, the coati, and the cats, about three-fourths; and in the ichneumon as much as four-fifths.

The nervous system.— On viewing the different orders of *mammifera* in the ascending series, the brain of the *Carnivora (fig.* 201 being an upper and a lateral view of that of the Lion) will be found to exhibit a higher degree

Fig. 201.



of developement than exists either in the *cetacea*, in any of the forms of the herbivora, or in the *marsupiata*; the *hemispheres* have here a well-marked superiority of developement over the *cerebellum* and *tabercala quadrigemina*. On the other hand the brain of the Carnivora is less developed anteriorly than in the *Qaadrumana*, the anterior lobes being somewhat narrowed and depressed, and the convolutions, (although deeper than in the orders just mentioned,) instead of the labyrinthine duplicatures which are observable in the *Quadramana* and in man, are, generally speaking, longitudinal in their direction, the principal being but two on each side of the median line, crossed by a transverse anterior one. The *cerebellam* is almost wholly uncovered as seen from above, not more than one-fifth of it lying under the posterior edges of the hemispheres. *The optic thalami*, however, are concealed not only from above but even on a lateral view, by the hemispheres. Of the *tubercula quadrigemina*, the posterior are the larger.

The eye possesses but few peculiarities of any importance. The relative proportions of the different humours are here more nearly equalized than in any order of the mammalia, at least in some of the genera, as the following comparative view will shew:—

	Aqueous.	Crystalline.	Vitreous.
Dog	$\frac{5}{21}$	$\frac{8}{21}$	$\frac{8}{21}$
Man	$\frac{5}{24}$	$\frac{4}{24}$	$\frac{24}{16}$
Ox	$\frac{5}{37}$	$\frac{14}{37}$	$\frac{18}{37}$

The vitreous humour, therefore, is much less than in either of the other cases, and the crystalline smaller in proportion than that of man. The crystalline lens in the Seal fulfils the general law which gives to it a degree of sphericity in relation with the aquatic habits of the animal. Thus the crystalline of fishes is absolutely spherical, that of the cetacea nearly so, and that of the seal and of the otter very much less flattened than in those animals which reside and seek their food on land. In the seal also the sclerotic is considerably thickened anteriorly and still more dense at the posterior part, whilst the middle zone is very thin and flexible,— a structure which must offer great facility for the action of the different muscles which compress the globe, and alter the relative proportion of its diameter to its axis. The form of the pupil differs in different groups. In the diurnal carnivora, and even in some nocturnal, it is permanently round; but in the cats it is perpendicular during its contracted state, and in a very bright light it is almost linear, but even in these it becomes perfectly round in the dark, and the ellipse which it forms in its contraction is more or less lengthened or acute according to the degree of light. The inner surface of the choroid is partially lined with a brilliant greenish tapetum, similar to that which is found in the ruminantia, and occupying nearly the same situation.

The lachrymal gland exists throughout this order, and the *glandula Harderi* is also found in its members as well as in the *ruminantia, pachydermata*, and some if not all the *rodentia*.

The organ of hearing is developed to a very considerable degree in most of the Carnivora. The external ear varies much in size and form; it is moderate in the cats, small in the bears, and rudimentary in the seals, but enormously large in the Fennec, a species of the family *Canidæ*. There is in these, as well as in many other mammiferous animals, especially the *rodentia*, a remarkable hollow appendage to the true tympanum, taking the place of the *mastoid process*, and probably performing the same office as the *mastoid cells*. This, in many, forms a large rounded process beneath the *cranium*. In the cats it is remarkably large and globose; in the bear, on the contrary, it is not visible externally. The object of this enlarged cavity is doubtless to give additional volume to the sounds which are brought to it, a circumstance especially required by the nocturnal habits of those species in which it is most largely developed. The *fenestra rotunda*, which is covered by a membrane stretched across it, is believed by Cuvier to be intended for the reception of the sounds produced by the resonance of the bony case just described; an opinion which is perfectly consonant with that of Scarpa, who considers the hole in question, with its membrane, as a sort of secondary tympanum. The *fenestra rotunda* is the larger of the two apertures of communication with the internal ear in the present order generally; in some of the most nocturnal, the cats and the civets, it is almost double the size of the *fenestra ovalis*. The passage answering to the *Eustachian tube* is remarkably short and can scarcely be called tubular; in the cats and civets it is nothing more than a narrow cleft in the suture which unites the *tympanum* to the true *petrous bone*.

The organ of smell is generally extensive in the carnivorous animals, and in addition to the principal apparatus of this sense, the different sinuses which augment the nasal cavity, particularly the frontal, are of considerable extent, especially in the *canidæ*. But the most remarkably developed of the surfaces on which the pituitary membrane is distributed, are those of the *superior* and *inferior turbinated bones*. The inferior are very complicated in their convolutions in the dogs, the bears, several of the cats, and particularly in the otters and the seals. This complication consists of repeated and multifarious bifurcation; and the ultimate divisions of this bone, which all assume a parallel direction, form a great number of channels which the air traverses in the act of inspiration, and which are all covered by the pituitary membrane. The *ethmoidal cells* and the *superior turbinated* bones are likewise greatly developed in the Carnivora, and particularly in those in which the before-mentioned structure of the inferior turbinated bones is most conspicuous—a remark which also applies to the numerous *foramina* in the cribriform plate of the ethmoid.

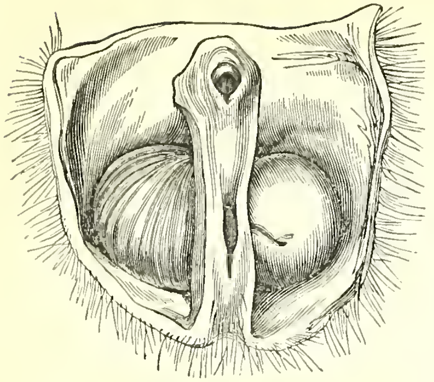
In the bear, and particularly in the coati, the cartilages of the nose form a complete tube, which is articulated moveably to the bony nostrils. The same structure is still more remarkable in the mole.

The organ of taste.—The structure of the surface of the tongue in the *Felidæ* is very remarkable with regard to the characters of the various papillæ with which it is furnished. The edges are everywhere covered with small soft conical papillæ, as well as with the *papillæ petiolatæ*, such as are found in most other animals. The whole of the middle part is covered with papillæ of two kinds very different from each other, and these two kinds are arranged in alternate rows in a quincuntial order. Those of one kind are soft, rounded, and appear to consist of bundles of filaments, which are supposed by Cuvier to be the ultimate extremities of the gustatory nerves, though this opinion appears from the recent observations of Breschet to be very doubtful. The others are conical and pointed, and each of them is covered by a sharp horny case curved a little backwards. It is these horny spines which render the tongue of the cats and the civets so exceedingly rough as that their continued licking would soon abrade the human skin. The tongue in all the other Carnivora scarcely differs in its structure from that of the human subject.

Secretions.— The urine. The structure of the kidney in some of the Carnivora is worthy of notice. Instead of being a compact and united mass as in man, it is subdivided into numerous portions similar to those of the human fœtus. In the cats this division is scarcely perceptible, the surface being only interrupted by superficial fissures or sulci. But in the bears, the otters, and the seals, the separation is so deep as to resemble in some sort a bunch of grapes. In the otter there are only ten of these divisions in each kidney; in the bear there are about fifty, and in the seal from a hundred and twenty to a hundred and forty. As this peculiarity of structure is found to exist in a still more remarkable degree in the *cetacea*, Cuvier has suggested whether it may be connected with the occasional longer or shorter suspension of respiration, as it obtains in the cetacea, the seals, the otters, which are often submerged, in the bears which remain torpid during the winter, and in the human fœtus which has never breathed. Its existence, however, in the elephant, the ox, and many other animals whose respiration is never interrupted, renders this explanation, as Cuvier himself observes, extremely unsatisfactory.

The existence of follicles producing a peculiar secretion is not an uncommon circumstance in several orders of the mammifera, as well as in many reptiles. In the Carnivora these follicles are found in almost all the genera, and in some attain to a large size. They are situated one on each side of the anus, and the excretory duct opens near the termination of the rectum. The substance usually secreted by these glandular surfaces is strongly odorous, and in some cases intolerably fetid. The annexed engraving (*fig.* 202) is taken from a specimen of *Gallictis vittata*, which I dissected some time since, and is selected, because it has not been before figured, and because the glands are of large size and very distinct. Each follicle is covered by a muscle of no inconsiderable strength, the object of which is to compress the follicle, and to force out the secretion through the duct. One of the follicles is represented covered by its

Fig. 202.



muscle; the other has had the muscle removed.

Besides these follicles there is in several species a pouch, somewhat resembling those above described, but differently situated. It is always single, and in the badger and hyena is placed between the anus and the tail; in the ichneumon it surrounds the anus, and in the civet it is found between the anus and the opening of the prepuce in the male, and between the anus and the vulva in the female. The secretion of this sac in the latter animal is well known as a scent of a most powerful musk-like odour. The sac opens by a longitudinal slit, and in the interior are seen two cavities in which the substance is secreted, and which are furnished with a muscular coat for its expression.

Generative system. — *Male organs.* The structure of the *testes* is similar to those of the other mammiferous animals, but they vary considerably in situation. In most of the genera, as in the bears, the cats, the martens, the hyenas, the ichneumons, &c. they are permanently suspended in a pendulous scrotum. In the civets they are enclosed under the skin of the perineum, and in the otter under that of the groin. In the seals, in which a pendulous scrotum would be exposed to continual danger of injury or destruction, they remain constantly within the abdomen, being retained in their situation by a production of the peritoneum, resembling the broad ligaments of the uterus.

The vesiculæ seminales do not exist in most of the Carnivora. They are found in the coatis, but not in their congeners. *The prostate gland*, or at least a glandular body apparently analogous to it, is found throughout the order. It varies in form and exceedingly in size; in the otter and the other *mustelidæ* it consists of a thin layer only, whilst in the dogs and cats it forms a large and conspicuous bulb around the urethra.

Cowper's glands also are found in many of these animals, but are wanting in the plantigrades, in the *mustelidæ*, the dogs, and the seals. In the *Felidæ* (the cats and the civets) and still more in the hyena, they are on the other hand of great size, and the muscle which envelopes them is of considerable thickness.

The penis is found to vary but little in its form and direction in this order. It is, in almost all, directed forwards, and contained within a sheath formed of an extension of the integuments of the abdomen. In the cats the extremity, during its relaxed state, is turned backwards, and the urine is consequently voided in that direction, but during its erect condition it assumes the same position as in the other Carnivora. Almost the whole of the carnivorous order possess a bone of the penis, of various size and length. The hyena is a remarkable exception, as in its congeners, the dogs, &c., it is of considerable size. This is the case also with the *ursidæ* and the *mustelida*; but in the cats and the ichneumon it is small. The anterior extremity of this bone is fixed in the *glans*, and the posterior is attached to the *corpus cavernosum*. In some genera, particularly the dogs, the *corpus spongiosum* undergoes a remarkable degree of tumefaction, which retains the two sexes *in coitu* for a considerable time.

The female organs.—The clitoris is found in all the Carnivora. It is contained in a sort of pouch within the vulva in the wolf, and at some distance in front of this part in the civet. In some of those species in which the penis of the male is furnished with a bone, the clitoris of the female has also a rudimentary one. This, however, is not constant. It is not found in the dogs or civets, but exists in the cats, the bears, and the otter.

The uterus is two-horned, and resembles that of most other mammifera.

The mammary glands are situated along the sides of the belly, and the number of teats varies greatly, without any general law as regards the affinities of the species. Most of the plantigrades have six; but the lion has four, the cat eight, and the panther six; the bitch, again, has from eight to ten.

The placenta consists, in the cat, the dog, the marten, and others, of a perfect zone surrounding the fœtus, and attached by its whole external surface to the uterus; in the polecat it is formed of two rounded masses connected together.

For the Bibliography, see that of Mammalia.

(T. Bell.)

CAROTID ARTERY, (human anatomy,) (*arteria carotis*; Gr. *καρωτις*; Fr. *carotide*; Germ. *die Carotis, Kopfpulsader;*) the great artery which on each side distributes blood to the different parts of the head. The term carotid, derived from *καρος*, *sopor*, appears to have been first applied to the arteries of the head by the ancients from a supposition that a state of drowsiness or deep sleep depended on compression or some other affection of these vessels exercising an influence over the circulation of the blood in its passage through them to the brain: in accordance with the same opinion they have been also called *arteriæ soporiferæ*.

The carotid arteries consist of—1st, *the primitive carotids*, of which the right arises from the arteria innominata, while the left comes directly from the arch of the aorta; 2d, *the external carotid;* and, 3d, *the internal carotid:* these last two vessels on each side being produced by the bifurcation of the primitive carotid.

Both primitive carotids are of equal size according to Bichat, Boyer, and Cloquet; neither Meckel nor Tiedemann make any remark as to a difference in their size, while, according to Soemmerring, the right is one-twenty-fifth larger than the left in the majority of instances.

The origin of the right carotid from the arteria innominata is opposite the right sterno-clavicular articulation. The left carotid arises from the transverse portion of the arch of the aorta behind the first bone of the sternum, on a plane with the centre of the junction of the cartilages of the first pair of ribs with that bone in front, and corresponding with the superior edge of the second thoracic vertebra posteriorly; owing to this difference in their origins, the left primitive carotid is from one inch to one inch and a quarter longer than the right, and is contained within the thorax in the commencement of its course; it may therefore be divided into a thoracic and a cervical portion.

The thoracic portion of the left primitive carotid, by which I mean that portion which extends from the origin of the artery to a point on a level with the sterno-clavicular articulation, has the following relations:—anteriorly it is covered by the left vena innominata, the remains of the thymus gland, some loose cellular tissue, and occasionally a few lymphatic glands; in front of these the origins of the sterno-thyroid and sterno-hyoid muscles separate it from the sternum; posteriorly it rests on the œsophagus, left recurrent nerve, the origin of the left subclavian artery, the left par vagum, the thoracic duct, and some loose cellular tissue, in addition to which the longus colli is interposed between it and the front of the spinal column; on its right side it is bounded by the trachea, and on its left by the phrenic nerve and the mediastinal portion of the left pleura, which gives a loose covering to a small portion of its surface, against which the internal side of the apex of the left lung is applied.

The right primitive carotid and the cervical portion of the left are of equal length, and have similar relations: at first, in the lower part of the neck these vessels of opposite sides are only separated by the breadth of the trachea: as they ascend, however, they diverge from each other, and are separated by the larynx and thyroid body: in their ascent they seem to pass backwards, owing to the prominence of the larynx forwards, but in reality they cannot recede, as they are closely applied to the front of the spinal column; they are not contorted in their course, nor do they furnish any branch until they arrive as high as the superior margin of the larynx, where each bifurcates by dividing into *the external* and *the internal carotids.*

Relations of the trunk of the Primitive Carotid.—Anteriorly the primitive carotid is covered by the three following layers of muscles from the sterno-clavicular articulation to the level of the cricoid cartilage; 1st, the platysma myoides, beneath which lies the superficial layer of the cervical fascia; 2d, the sternal portion of the sterno-cleido-mastoid; and 3d, by the sterno-hyoid, sterno-thyroid, and the omo-hyoid, which latter muscle crosses the sheath of the artery, having its internal edge connected with the outer edge of the sterno-thyroid by a dense fascia, a part of the deep layer of the cervical fascia, which is firmly connected to the posterior margin of the clavicle inferiorly: between the lower part of the sterno-mastoid and the front of the artery there is an interval of about an inch on the left side, and something less on the right, in consequence of the origin of the right carotid being so much more anterior on that side; this interval is filled by cellular and adipose tissue, some large veins, one or more of the sub-clavicular branches of the cervical plexus, and occasionally a few lymphatic glands; at the level of the cricoid cartilage the sterno-mastoid passes backward, and the omo-hyoid coming from beneath, it passes forwards to its insertion into the os hyoides. Above the crossing of these two muscles the carotid has no muscular covering, except the platysma, from which it is separated by cellular membrane, several veins from the thyroid body and larynx, and some lymphatic glands; the nervus descendens noni also lies in front of the primitive carotid at its upper portion, being found sometimes within, sometimes outside, and occasionally embedded in the substance of the wall of its sheath; the thyroid body also generally overlaps the carotid by its outer edge.

Posteriorly the carotid is bounded by the longus colli and rectus capitis anticus major, which separate it from the anterior surface of the spinal column; the cervical cord of the sympathetic nerve and its superior and middle cardiac branches are closely connected to the posterior part of its sheath; the vertebral artery and vein are behind it at its lower part; and higher up it crosses the inferior thyroid artery at a point corresponding to that at which it is covered in front by the omo-hyoideus; sometimes the inferior thyroid crosses over the carotid: the arteria cervicalis ascendens often lies behind the carotid towards the upper part of the neck; moreover, the recurrent nerve on the right side, in its course from behind the subclavian artery to the side of the trachea, passes behind the origin of the right carotid. From the relations of the primitive carotid posteriorly, it is evident that it can be most effectually compressed against the front of the spinal column, but to continue such pressure for any length of time would obviously be followed by injurious effects, from the lesion to which the nerves behind the sheath of the vessel would be thus subjected.

Externally the carotid artery is bounded by the internal jugular vein and the pneumo-gastric nerve, both of which are contained within its sheath; the vein when distended advances in front of it and partly conceals it; the nerve lies in the posterior part of the sheath, behind and between the artery and vein, more closely attached to the latter vessel; on the left side the internal jugular vein lies closer to the carotid, in front of which it passes at the lower part of the neck in its course to the vena innominata; on the right side the jugular vein is separated from the carotid inferiorly by a small intervening space, principally occupied by cellular tissue, in consequence of the vein of this side descending to join the commencement of the superior cava in a perpendicular course further from the mesial line than the point at which the carotid is given off from the arteria innominata.

Internally the carotid is bounded by the trachea at its lower part; higher up by the thyroid body and the inferior constrictor of the pharynx, by which it is separated from the cricoid and thyroid cartilages; the recurrent nerve also lies on its inner side, but separated from it by a quantity of loose cellular tissue; in addition to the foregoing relations, the left carotid lies in contact with the œsophagus.

The varieties to which the origins of the carotid arteries are subject are the following: 1. the right carotid sometimes arises separately from the aorta; this variety occurs when there are four large trunks arising from the arch of the aorta, of which the right carotid is the first, and the right subclavian the last in order; 2. sometimes the arteria innominata gives origin to the left carotid, in addition to the right carotid and right subclavian, in which case the left carotid has to cross in front of the lower part of the trachea to enter upon its cervical course; 3. the right and left carotids sometimes spring from a common trunk, which arises from the arch of the aorta between the right and left subclavian arteries; in this variety as well as in the preceding, the situation of the carotids in front of the trachea exposes them to the danger of being wounded in the operation of tracheotomy, in performing which the surgeon should always be prepared to meet with the existence of such irregularities of distribution: 4. the left carotid sometimes arises from a left arteria innominata, which also gives off the left subclavian. (See Aorta.)

The bifurcation of the primitive carotid most frequently occurs opposite the superior margin of the thyroid cartilage, in front of the third cervical vertebra; it may, however, take place above or below that point. It sometimes bifurcates opposite the cornu of the os hyoides, or, which rarely happens, behind the angle of the lower jaw; in cases where the bifurcation is higher than usual, the primitive carotid often furnishes some of the branches ordinarily arising from the external carotid. The high bifurcation is an approximation to that condition of the carotid in which no bifurcation takes place, but where the primitive carotid, after having given all the branches which the external carotid usually supplies, enters the cranium and becomes the internal carotid. 2. The primitive carotid sometimes bifurcates lower down in the neck than usual. I have seen such a bifurcation occurring on both sides in an old female subject, as low as the inferior border of the thyroid body.

The bifurcation of the carotid has the same relation to the larynx at all periods of life: it is more distant from the angle of the jaw in the infant than in the adult; the depth of the lower jaw in the former being much less, owing to the non-development of the roots of the teeth and alveolar processes: in old persons who have lost their teeth, and whose alveolar processes have been absorbed, the jaw being in the edentulous condition, the angle of the jaw is carried forward and thus removed farther from the bifurcation of the carotid. By depressing the head the angle of the jaw is brought nearer to the bifurcation; while the distance between these parts may be considerably increased by throwing the head backwards.

The bifurcation of the primitive carotid gives origin to the external and internal carotids; the former of these supplies the larynx, thyroid body, pharynx, throat, face, and external parts of the head; the latter is distributed to the brain and the internal parts of the organs of hearing and vision. These two vessels lie close together at their origins. The internal is at first more superficial and more external in situation than the external, but becomes the more deeply situated of the two as they ascend. They are nearly of equal size in the adult when the bifurcation occurs at the usual place; while in the infant the internal is larger than the external.

The external carotid, (*arteria carotis externa, superficialis vel anterior, Sœmm. faciale* of *Chaussier,)* extends from the bifurcation of the primitive carotid to the neck of the condyle of the lower jaw, where it terminates by dividing into the superficial temporal and internal maxillary arteries. In this course it describes a curve, the concavity of which is outwards and a little backwards, as it ascends between the ear and the ramus of the lower jaw. At first it is superficial, merely covered by the integuments, platysma and cervical fascia; it then ascends under the ninth or hypoglossal nerve and the posterior belly of the digastric and stylo-hyoid muscles, and buries itself in the substance of the parotid gland. Internally it rests at first on the commencement of the internal carotid, then over the middle constrictor of the pharynx, the stylo-pharyngeus and stylo-glossus muscles, the glosso-pharyngeal nerve and the styloid process of the temporal bone; the superior and inferior pharyngeal nerves coming from the par vagum also pass under it in their course to the pharyngeal plexus. The part of the parotid gland which the external carotid first enters is the internal surface of its lower extremity, consequently the whole thickness of the gland covers it at that part; but in passing through the gland the artery becomes more superficial as it ascends and is covered only by a very thin layer of the glandular substance at the place where it terminates. The branches of the portio dura forming the *pes anserinus* cross the course of the carotid in the substance of the gland, being superficial to it and separated from it by the posterior facial vein and part of the glandular substance.

*Branches of the external carotid.**—The external carotid gives off eight principal branches; three anteriorly, *the superior thyroid*, *the lingual*, and *the labial or facial;* two posteriorly, *the occipital* and *posterior aural;* one internally, *the ascending pharyngeal;* and two superiorly, *the superficial temporal* and *internal maxillary*, besides several smaller branches, the number and origins of which are subject to great irregularity, and which are distributed to the sterno-mastoid muscle, the superior cervical ganglion of the sympathetic nerve, the digastric, stylo-hyoid, stylo-pharyngeus, and stylo-glossus muscles, &c., to the parotid gland, the external ear, and to the integuments.

Anterior branches.—1st. *The superior thyroid artery (A. thyroidea superior)* generally arises opposite the cornu of the os hyoides a few lines above the bifurcation of the primitive carotid; in some rare cases it comes from the trunk of the primitive carotid: it has been also seen to arise from the lingual. It takes a tortuous course downwards and forwards, and passing under the omo-hyoid, sterno-thyroid, and sterno-hyoid muscles, arrives at the superior and external part of the thyroid body to which it is chiefly distributed: at first it is superficial, being covered by the integuments, platysma, cervical fascia, some lymphatic glands and small veins coming from the superior part of the larynx to join the internal jugular; it is also crossed by the branch of the nervus descendens noni which is sent to the superior belly of the omo-hyoid muscle, and the superior laryngeal and several filaments from the sympathetic nerves to the larynx, &c. lie beneath it. In its course the superior thyroid artery, besides furnishing a variable number of smaller branches, to the muscles and other parts in its vicinity, generally gives off the three following: *a. The hyoidean branch*, which runs along the inferior border of the os hyoides between the hyo-thyroid muscle and the membrane of the same name, to both which it gives branches; it inosculates with the corresponding artery of the opposite side in the mesial line, and with the lingual by a twig which passes up on the front of the body of the os hyoides. The hyoidean branch is often absent. *b. The superficial* branch passes downwards and outwards over the sheath of the carotid artery to the sterno-mastoid muscle, to which and the neighbouring lymphatic glands and integuments it is finally distributed, anastomosing in the substance of the sterno-mastoid with branches coming from the occipital above and others from the thyroid axis inferiorly. *c. The laryngeal* often arising from the external carotid, an occurrence which, according to Meckel, takes place in one case in eight, passes into the larynx through the hyo-thyroid membrane, sometimes through a hole in the thyroid cartilage; it usually accompanies the superior laryngeal nerve: its branches are lost in the internal muscles and mucous membrane of the larynx and the epiglottis. Before it enters the larynx it gives branches, some of which ascend to anastomose with the hyoidean, others descend to the thyroid body; one of these latter is remarkable for running across the front of the crico-thyroid membrane to anastomose with a similar branch from the opposite side; it generally lies in the situation in which laryngotomy is performed. Having given off the above-mentioned branches, and arrived at the superior extremity of the thyroid body, the thyroid artery divides into two branches, one of which descends along its external edge, sending off numerous branches which are lost in its substance, anastomosing freely with the inferior thyroid, the other branch descends coursing along the superior border of that body on which it expends its branches, and arriving at the mesial line below the cricoid cartilage, anastomoses with the corresponding artery from the opposite side: occasionally this branch supplies the small artery which crosses the crico-thyroid membrane.

2. *The Lingual Artery (A. lingualis)* arises after the thyroid, and sometimes, but rarely, from a common trunk with the thyroid, comes at other times and not unfrequently from the facial. This artery forms in its course a considerable curve, the convexity of which is upwards; it passes forwards and inwards above the cornu of the os hyoides, between the middle constrictor of the pharynx and hyo-glossus, and mounts up towards the base of the tongue, between the hyo-glossus and sublingual gland which lie to its outer side, and the genio-glossus which is internal to it; then taking a horizontal direction, it passes forwards under the name of *ranine artery*, in company with the hypo-glossal nerve, coursing between the genio-glossus and lingualis muscles, as far as the point of the tongue where it anastomoses with its fellow of the opposite side. After its origin and before it passes under the posterior edge of the hyo-glossus muscle, this artery runs superficially beneath the common coverings of the neck, lying on the middle constrictor of the pharynx above the cornu of the os hyoides; superior to it lie the tendon of the digastric muscle, the stylo-hyoid muscle and the hypo-glossal nerve, which after sending a filament across it to the hyo-thyroid muscle, continues its course forwards on the cutaneous surface of the hyo-glossus muscle which separates the lingual nerve and artery in this part of their course.

Branches.—Having given a few inconsiderable twigs to the middle constrictor, stylo-glossus, digastric, and stylo-hyoid muscles, and to the sublingual gland, &c.; the lingual

* In the arrangement of the branches of the external carotid artery the writer follows that of Meckel. See his Anatomie Descriptive, &c. translated into French by Breschet and Jourdan.

artery sends off the following branches. *a, The hyoidean* branch, arising at the external edge of the hyoglossus muscle, passes between the genio-hyoideus and genio-glossus, and coming forward in the mesial line, descends over the front of the body of the os hyoides, and anastomoses with the hyoidean branch of the thyroid artery, giving branches to the muscles, in the vicinity of which it passes and to the integuments. *b, The dorsalis linguæ*, arising under cover of the hyoglossus, passes upwards and outwards, crossing the stylo-glossus and distributes its branches over the posterior part of the dorsum of the tongue, the tonsils, velum palati, and epiglottis, where it anastomoses with the laryngeal branch of the superior thyroid. At the internal edge of the hyoglossus the lingual artery divides into the *sublingual* and *ranine*. *c, The sublingual* branch passes forwards between the mylo-hyoid and genio-glossus muscles and above the sublingual gland, to which it is principally distributed, as well as to the muscles of the tongue and the mucous membrane of the mouth. Occasionally we find the place of the sublingual artery supplied by the submental, a branch of the facial. *d, The ranine* artery, which is the continuation of the trunk of the lingual, passes forward between the genio-glossus and lingualis, and running along the under surface of the tongue by the side of the attachment of the frænum, sends numerous branches into the substance of that organ, and ends by anastomosing with the ranine of the opposite side. It is this artery which is endangered if the scissors be directed too much upwards in dividing the frænum linguæ in children.

3. *The labial artery*, called also *facial or external maxillary, (a. facialis v. maxillaris externa,)* varies very much in its origin, size, and the extent of its distribution. It is usually the largest of the three anterior branches of the external carotid, and supplies the whole of the anterior part of the face; sometimes, however, it only extends as far as the angle of the mouth, beyond which its place is supplied by the temporal artery. There is, perhaps, no other artery which presents so many varieties, even on opposite sides of the body in the same subject. From its origin it proceeds, in a tortuous course, inwards and forwards, towards the internal part of the angle of the lower jaw, covered by the hypoglossal nerve, the digastric and stylo-hyoid muscles: it then passes between the lower jaw and submaxillary gland, lodged in a groove in that gland; after which it turns over the inferior border of the lower jaw, and arrives on the external surface of that bone a little in front of the anterior edge of the masseter muscle: from this it ascends tortuously towards the commissure of the lips, covered by the skin and the platysma; thence passing upwards and inwards under the zygomatic muscles, and over the buccinator and levator anguli oris, it continues to ascend in the groove between the cheek and the upper lip and by the side of the nose, to the internal canthus of the eye, where, very much diminished in size, it terminates by anastomosing with the nasal branch of the ophthalmic artery.

Branches.—The branches of the labial artery are very numerous. *a, The inferior palatine*, which arises from the labial close to its origin; this vessel sometimes comes from the trunk of the carotid itself, it passes upwards between the stylo-pharyngeus and stylo-glossus, to which it gives branches: it then attaches itself to the superior and lateral part of the pharynx, supplying this region, the tongue, and the tonsil. Having reached the velum palati, it divides into many branches, which are distributed to the muscles, mucous membrane, and glands of that organ, and to the Eustachian tube. These branches anastomose with the superior palatine branch of the internal maxillary. *The tonsillitic artery, (arteria tonsillaris* of Soemmerring,) enumerated as a distinct branch of the labial by Professor Harrison, is, more properly speaking, a branch of the inferior palatine.

In passing through the sub-maxillary gland, the labial artery gives off several branches to this gland, the internal pterygoid muscle, and the mucous membrane of the mouth: as it is about to turn over the side of the lower jaw, there arises from it a branch of more considerable size, namely, *b, the submental branch.* This artery passes forwards beneath the base of the lower jaw, covered by the platysma and anterior belly of the digastric, between which and the mylo-hyoideus it takes its course towards the symphysis of the chin, distributing branches to supply the muscles and integuments in this region and to anastomose with the sublingual; some of its branches mount over the chin and communicate with the arteries of the lower lip: the submental artery sometimes furnishes the sublingual, and at other times it is given off by this latter.

From the inferior border of the lower jaw to the commissure of the lips, the labial gives several branches, some of which are anterior and some posterior: the posterior are comparatively insignificant branches distributed to the masseter, platysma, buccinator, parotid gland and duct, the cellular tissue and integuments of the cheek, which communicate with branches of the transverse facial. Besides smaller branches given off anteriorly to the lips, there are two considerable branches and one of lesser size, which require a more particular description; viz. *c, the inferior labial coronary* arises about midway between the commissure of the lips and the base of the lower jaw, it passes under the triangularis oris muscle, to which, as well as to the quadratus, levator labii inferioris, and mucous membrane of the mouth, it gives numerous branches and anastomoses with its congener, and the mental branch of the inferior dental. This artery is sometimes smaller on one side than on the other; it is sometimes absent on one side, when its place is supplied by the artery of the opposite side; sometimes it arises from the superior labial coronary; sometimes it is double. After having given off this branch, the facial artery continues its course upwards and inwards, and, opposite the commissure of the lips, gives off *d, the superior labial coronary artery.* This vessel passes inwards among the fibres of the orbicularis oris, runs above the free border of the upper lip nearer to its mucous membrane than to its cutaneous surface, gives branches to the various parts composing the upper lip, and meets the coronary of the opposite side, with which it very freely anastomoses. The superior labial coronary always sends off from the place where it anastomoses with that of the opposite side a branch, which ascends towards the septum of the nose, and which is called the artery of the septum of the nose, *(arteria septi nasi.)* The place of this artery is sometimes occupied by two or more branches; it divides, near the septum of the nose, into at least two branches, which pass, one on either side, along the inferior border of the septum to the extremity of the nose, where it anastomoses with branches of the lateral nasal: sometimes the superior coronary gives off a branch *(ramus pinnalis)*, as it passes the ala of the nose, to which, and the external part of the nostril, it is distributed.

After the origin of the superior labial the facial artery is reduced to a very small size, and its continuation is by some called the external nasal, *arteria nasalis externa communis.* It continues to pass obliquely upwards, forwards, and inwards under the levator labii superioris, to which it gives branches: after anastomosing with the infra-orbital artery and giving off branches, which pass forward on the lateral surface of the nose, namely, *e, laterales nasi,* and *f, dorsales nasi,* which freely anastomose with each other, with the artery of the septum, and those of the opposite side on the dorsum of the nose, it emerges from between the two heads of the levator labii superioris, and becoming subcutaneous, terminates at the inner canthus of the eye by anastomosing with the termination of the nasal branch of the ophthalmic, at which place it has received the name of the *angular artery.*

Irregularities of the labial or facial artery. It sometimes happens that the facial artery is smaller than usual, and terminates at the angle of the mouth or even below the situation of the usual origin of the inferior coronary; in this case the transverse facial branch of the temporal generally furnishes the branches which the coronary has failed to produce; on the other hand the labial artery is sometimes of a larger size than usual, as happens when it furnishes supernumerary branches, such as the ranine or sublingual. The facial artery is the principal source of communication between the superficial and deep branches of the external carotid by its anastomoses with the infra-orbital, nasal and dental arteries; and of the external carotid with the internal, by its anastomoses with the ophthalmic.

Internal branch of the external carotid, Inferior pharyngeal artery, (a. pharyngea inferior v. ascendens,) arises commonly from the internal side of the external carotid close to its origin, sometimes from the bifurcation of the primitive carotid, more rarely from the internal carotid, and occasionally from the occipital; sometimes its place is supplied by the inferior palatine or by branches from the trunk of the facial; sometimes it is double, in which case only one of its branches arises from the external carotid, the other being furnished by one of the smaller arteries already mentioned, or by the internal carotid; this artery is always the smallest branch of the external carotid; it passes perpendicularly upwards internal to the external carotid between the trunk of that vessel and the pharynx, lying on the rectus capitis anticus major muscle, and closely related to the superior cervical ganglion of the sympathetic. Having furnished branches from its inner side, both ascending and descending, to the constrictors of the pharynx and other muscles, which also supply the mucous membrane, and from its external side to the deep muscles of the neck, it terminates at the basis cranii, near the petrous portion of the temporal bone, by giving off its terminal branches, of which one, *the proper pharyngeal,* is principally distributed to the parietes of the pharynx, and communicates by anastomosis with the inferior palatine from the superior thyroid; a second, *the posterior meningeal artery,* enters the cranium by the foramen lacerum posterius, or by an opening in the vicinity of the condyle of the occipital bone, and is distributed to the dura mater lining the inferior occipital fossa: and a third ascends to the basis cranii, and perforates the cartilaginous lamella, which fills up the foramen lacerum posterius, to enter the cranium and be distributed to the dura mater.

Posterior branches of the external carotid.—1st. *The occipital artery (a. occipitalis)* arises from the posterior side of the external carotid, opposite the lingual or the facial; it sometimes but rarely comes from the internal carotid; it passes at first a little obliquely backwards along the lower border of the posterior belly of the digastric muscle which overlaps it; it crosses over the ninth pair of nerves which winds beneath it just at its origin, the internal carotid artery, internal jugular vein, and spinal accessory nerve; and passing backwards between the transverse process of the atlas and the mastoid process of the temporal bone it is lodged in a groove in this latter bone, which is internal to the insertion of the posterior belly of the digastric; it crosses the outer border of the rectus capitis lateralis muscle, and continuing its course beneath the sterno-cleido-mastoid, trachelo-mastoid, splenius capitis and trapezius, and over the obliquus superior and complexus, it ascends tortuously over the superior part of the occipital bone, where it becomes cutaneous and anastomoses with branches from the temporal, posterior auris, and opposite occipital. The first branches of the occipital are small, and are distributed to the sterno-mastoid, digastric, and stylo-hyoid muscles, and to the lymphatic glands in the neighbourhood; the branches which enter the sterno-mastoid are sometimes considerable, and anastomose freely in the substance of that muscle with the branches which it receives from the superior thyroid.

The sterno-mastoid muscle very frequently receives a large branch at this part arising distinctly from the external carotid. This Professor Harrison considers should be classed among the regular branches of the external carotid, and he has described it under the name of *a. sterno-mastoidea.**

While the occipital artery is covered by the sterno-mastoid, trachelo-mastoid, and splenius, it gives branches to these muscles, some of which descending anastomose with branches of the cervicalis profunda and the vertebral; those which ascend are distributed to the superior attachments of these muscles; amongst them there is one branch occasionally found which penetrates into the cranium by the mastoid hole, and is distributed to the dura mater, under the name of posterior meningeal of the occipital.

When the occipital artery comes out from beneath the splenius muscle it divides into those branches which are distributed over the posterior surface of the occipital bone, supplying the occipito-frontalis and the scalp, together with the pericranium, and anastomosing, as already mentioned, with the opposite occipital, posterior auris, and temporal. One of these branches frequently enters the cranium by the parietal hole, and spreads over the dura mater.

The occipital artery sometimes gives small twigs, which enter the cranium by the foramen lacerum posterius and the anterior condyloid foramen.

2d. *A. posterior auris, v. auricularis posterior,* arises immediately after the occipital, in the substance of the parotid gland; it is generally a much smaller vessel than the latter, from which it is mostly separated by the stylo-hyoid muscle: sometimes it comes from the occipital. It passes upwards and backwards under the parotid gland between the mastoid process of the temporal bone and the cartilaginous tube of the ear; it first sends branches to the parotid gland, the stylo-hyoid muscle, the posterior belly of the digastric and the external ear; it then gives off the *stylo-mastoid artery,* which, among other branches to the external ear, gives off one to be distributed to the membrana tympani. Then the stylo-mastoid traversing the aqueduct of Fallopius finds its way into the cavity of the tympanum, on the lining membrane of which, and its prolongation into the mastoid cells, its branches are expended, where it anastomoses with a branch of the middle meningeal, which enters the hiatus Fallopii, and arrives in the tympanum along with the chorda tympani nerve. Sometimes the stylo-mastoid artery comes from the middle meningeal.

When the posterior auris gets to the front of the mastoid process it divides into two branches, one of which is anterior and the other posterior; the former spreads its branches over all parts of the internal surface of the ear; the latter ascends in front of the mastoid process, passes under the posterior auris muscle, and divides into many branches, which are distributed to the occipito-frontalis and temporal muscles, integuments, &c.

These branches anastomose with the temporal and occipital arteries.*

While traversing the parotid gland the external carotid gives several small branches to the masseter and pterygoid muscles, to the substance of the gland itself, and a few to the front of the external ear; occasionally it gives origin to the transversalis faciei in this course.

Behind the neck of the condyle of the lower jaw the external carotid divides into its two superior and terminal branches, the *temporal* and *internal maxillary.*

1. *Temporal artery, (a. temporalis.)* The temporal artery ascends at first a little obliquely outwards between the ramus of the jaw and the tube of the ear, covered by the parotid gland; crossing the zygoma at its posterior part, and passing under the anterior auris muscle, it mounts up over the temporal aponeurosis, and becomes subcutaneous for the remainder of its course.

Immediately after its origin the temporal gives off anteriorly a very considerable branch, which is called the *transversalis faciei:* this artery sometimes arises from the trunk of the external carotid; it passes forward over the neck of the condyle of the lower jaw, and, crossing the masseter muscle, runs superior to the duct of Steno, which it accompanies across the face; it anastomoses with the labial, buccal, and infra-orbital arteries. The branches which the transversalis faciei usually gives off are distributed to the parotid gland and its duct, the masseter, zygomatic, and orbicularis palpebrarum muscles, and the integuments. I have seen an instance in which this artery arose from the external carotid opposite the angle of the jaw, beneath which it passed forwards, and joined the labial at the anterior edge of the masseter muscle.

When the temporal artery has arrived at the zygoma, it gives a branch called *middle temporal,* which pierces the temporal aponeurosis, and ascends in the substance of the temporal muscle, to which it is distributed, and which anastomoses with the deep temporal arteries.

Having given off a few small branches to the parotid gland, integuments, and external ear, the temporal artery ascends on the temporal aponeurosis, and divides into two branches, the anterior and posterior. The anterior branch ascends in a serpentine course towards the forehead, and sends off many branches, which are distributed to the occipito-frontalis, the orbicularis palpebrarum, and integuments, and which anastomose with the superciliary and

* Surgical Anatomy of the Arteries of the Human Body, vol. i.

* [The surgical anatomist cannot fail to notice the relation of the posterior auris artery to the portio dura nerve, as it lies superficial to and nearer the mastoid process than that nerve, so as to be considerably, although not necessarily, endangered when the operator proceeds to divide the nerve at its emergence from the stylo-mastoid foramen.—ED.]

frontal branches of the ophthalmic and with the opposite temporal. The posterior branch passes upwards and backwards in a tortuous course, and supplies the integuments, temporal aponeurosis, pericranium, &c. These branches anastomose with the anterior branch, with the opposite temporal, the occipital, and posterior auris.

2. *The internal maxillary artery, (a. maxillaris interna,)* is larger than the preceding; immediately after its origin it passes downwards and inwards under the neck of the condyle of the lower jaw; it then mounts forwards and inwards between the temporal and external pterygoid muscles, and usually passing between the two origins of the latter, it enters the pterygo-maxillary fossa, where it ascends as high as the level of the inferior wall of the orbit, opposite which it takes a horizontal direction. At this place it divides into numerous branches, which are distributed on one side inwards towards the nose, and on the other side to the external part of the face.

The branches of the internal maxillary are, *a. the middle meningeal, b. the inferior dental, c. the posterior deep temporal, d. the masseteric, e. pterygoid branches, f. the buccal, g. the anterior deep temporal, h. the alveolar, i. the infra-orbital, l. the superior palatine, m. the vidian, n. the pterygo-palatine,* and *o. the spheno-palatine:* in addition to these the internal maxillary artery gives several branches to the cellular tissue and other parts surrounding it.

a. The middle meningeal artery (a. meningea media, spinosa) arises from the superior part of the artery and passes directly upwards on the inside of the external pterygoid muscle, to which, to the superior constrictor of the pharynx and muscles of the velum palati it sends branches, and passing between the tensor palati muscle and internal lateral ligament of the temporo-maxillary articulation, enters the cranium through the foramen spinale of the sphenoid bone, and immediately gives off some small branches, which pass through the hiatus Fallopii to the cavity of the tympanum, where they anastomose with the stylo-mastoid artery; other branches pass forwards towards the orbit into which some of them occasionally enter by the foramen lacerum. The meningeal artery then divides into two branches, an anterior and a posterior; the anterior, which is the larger, might be considered as the continued trunk; it mounts forwards towards the anterior inferior angle of the parietal bone, where it is lodged in a groove, and sometimes in a canal in the substance of that bone. This branch at first gives twigs to the foramen lacerum, which anastomose with the lachrymal; after which it mounts on the parietal bone, principally following the course of the coronal suture, sending its branches upwards and backwards between the dura mater and the inner surface of the parietal bone. The posterior branch passes backwards in a curved direction on the inner surface of the squamous portion of the temporal bone, and advancing towards the inferior border of the parietal bone, is expended on the posterior and lateral part of the dura mater. The branches of the middle meningeal artery spread over the external surface of the dura mater, and occupy the grooves which are disposed in an arborescent form on the internal surface of the parietal bone. The middle meningeal artery anastomoses with that of the opposite side and with the other arteries of the dura mater.

b. The inferior maxillary or inferior dental artery sometimes coming from the middle meningeal, descends to the posterior dental hole by which it enters the dental canal, passing between the inner surface of the ramus of the jaw and the outer surfaces of the internal pterygoid muscle and the internal lateral ligament of the temporo-maxillary articulation, to which it gives small twigs: before it enters the dental hole, it gives off a small branch, which passing downwards and forwards in a groove on the inside of the lower jaw, is distributed to the mylo-hyoid muscle and mucous membrane of the mouth. In the dental canal this artery passes forwards beneath the alveoli of the molar teeth, sending upwards in its course several branches which penetrate into the alveoli, and enter the cavities of the teeth by the holes in their roots; having arrived opposite the mental hole, it sends a branch which passes onwards beneath the alveoli of the canine and incisor teeth, to which it is distributed; while the continuation of the artery coming out through the mental hole is distributed to the muscles of the lower lip, where it anastomoses with the labial.

c. The posterior deep temporal artery arises after the dental; it passes upwards between the temporal and external pterygoid muscles, and sinking into the substance of the former, divides into a great number of branches, which spread over the squamous portion of the temporal bone, and are distributed to the temporal muscle and pericranium. This artery anastomoses with the anterior deep temporal, the middle, and the superficial temporal.

d. The masseteric is a small branch often arising from the posterior deep temporal; it passes outwards between the posterior border of the temporal muscle and the condyle of the lower jaw, and enters the masseter muscle, where it anastomoses with the transversalis faciei.

e. The pterygoid arteries are irregular as to number, size, and origin; they either come from the trunk of the internal maxillary or the posterior deep temporal, and are distributed to the pterygoid muscles.

f. The buccal artery does not always arise from the internal maxillary itself; it sometimes comes from the anterior deep temporal, the alveolar, or infra-orbital. It passes downwards and forwards between the internal pterygoid muscle and ramus of the lower jaw, and advances over the surface of the buccinator muscle, to which it gives branches, as well as to the zygomatic and other muscles of the lip: it anastomoses with the labial, infra-orbital, and transversalis faciei.

g. The anterior deep temporal arises from the internal maxillary, near the outer wall of the temporal fossa beneath the temporal muscle, to which it is distributed; some of its branches enter the orbit through the malar bone, and spread over the lachrymal gland, communicating with the lachrymal artery.

h. The alveolar artery descends forwards over the superior maxillary bone, very tortuous in its course; it gives two or three twigs, which pass into the inferior and posterior dental foramina to be distributed to the lining membrane of the antrum maxillare and the molar teeth; the other branches of the alveolar artery are distributed to the gums, to the buccinator, to the periosteum of the superior maxillary bone, and to the cellular substance of the cheek: they communicate with the infra-orbital, labial and buccal.

i. The infra-orbital artery arises from the internal maxillary at the superior part of the pterygo-maxillary space; it enters the infra-orbital canal, through which it passes forwards and inwards, sending branches into the orbit and maxillary sinus; passing out by the infra-orbital hole it comes forward on the face behind the levator labii superioris, and terminates in a number of branches, which pass into the muscles of the upper lip, and anastomose with the labial, alveolar, buccal, and nasal branch of the ophthalmic.

The remaining branches of the internal maxillary are given off in the pterygo-maxillary space; of these the first is

l. The superior palatine descends behind the tuberosity of the superior maxillary bone in the palato-maxillary canal: it usually gives off two branches, which descend through holes in the pterygoid process of the palate bone, and are distributed to the soft palate; while the trunk of the superior palatine passing out of the posterior palatine hole, directs itself forwards and inwards in a groove on the surface of the hard palate, and divides into numerous branches, which are distributed to the mucous membrane and glands of the palate, to the gums, and to the superior maxillary bone; one of these branches sometimes passes up through the foramen incisivum to the nasal fossæ.

m. The vidian artery is an insignificant branch which traverses the vidian canal from before backwards, and coming out of its posterior opening is distributed to the Eustachian tube and the roof of the pharynx: it anastomoses with the inferior pharyngeal.

n. The pterygo-palatine or *superior pharyngeal* is a small insignificant branch, which passes through the pterygo-palatine hole, and is distributed like the former to the roof of the pharynx and Eustachian tube, sending some branches to the sphenoid bone and the membrane lining its sinuses.

o. The spheno-palatine artery may be considered the termination of the internal maxillary; it enters by the spheno-palatine hole into the posterior part of the nasal fossæ, and divides into two principal branches; an external and an internal; the internal branch passing across the roof of the nasal fossæ arrives at the septum, on which its branches are principally distributed; it also supplies branches to the roof of the pharynx and the posterior ethmoidal cells; the external branch descends on the lateral wall of the nose, sending its branches over the spongy bones and into the antrum maxillare: these branches anastomose with the ethmoidal branches of the ophthalmic artery.

The internal carotid artery, (*carotis interna seu cerebralis, Sœmm. cérébrale antérieure, Chaussier.*) This artery is larger than the external carotid in the fœtus, but in the adult is only equal in size to that vessel, aud sometimes even smaller. At its origin it takes a curve outwards so as to get external to the commencement of the external carotid; it then mounts upwards and forwards in front of the three superior cervical vertebræ, and making a few contortions along the side of the pharynx, enters the foramen caroticum of the temporal bone, traversing the carotid canal of that bone internal to the cavernous sinus, perforates the dura mater internal to the anterior clinoid process of the sphenoid bone, where it divides into two large branches, the anterior and middle cerebral.

The internal carotid artery has the following relations from its origin to the place where it enters the foramen caroticum: anteriorly it has the external carotid and its branches in contact with it at its origin, also the hypoglossal or lingual nerve, and as it passes under the digastric muscle it also slips beneath the following parts which lie between it and the external carotid, the styloid process, with the muscles attached to it, part of the parotid gland, the glosso-pharyngeal and inferior pharyngeal nerves.

Posteriorly it lies on the rectus capitis anticus major, having the par vagum and superior laryngeal nerve behind it, and higher up the trunk of the hypo-glossal nerve coming from between it and the internal jugular vein.

The internal jugular vein bounds it externally at first, but passes to its posterior side above where it gets to the internal side of the root of the styloid process. Internally the carotid artery lies on the side of the pharynx to which it is more closely applied towards its upper part, lying on the stylo-glossus and the outer surface of the superior constrictor muscles, which with some cellular membrane and a venous plexus separate it from the tonsil, external and posterior to which it lies, at the distance of from six to eight lines in the natural state of the parts; but when that gland is enlarged in consequence either of acute inflammation or chronic disease, the distance between it and the artery is diminished so much as to expose the latter to some risk of being wounded in opening abscesses in the tonsil, an occurrence of which the records of experience are not without examples. In this stage of its course the internal carotid seldom gives any branches; occasionally, however, the inferior pharyngeal or the occipital arises from it. Having entered the carotid canal, the artery ascends vertically, then turns forwards and inwards, and passing out of the canal opposite the posterior clinoid process, it takes a second turn upwards, then forwards along the side of the sella turcica, between the layers of the dura mater which include the cavernous sinus, between which latter and the bone the artery is situate. At the anterior extremity of the side of the sella turcica it makes a third turn upwards under the anterior clinoid process, and passing backwards and a little inwards it perforates the dura mater between the internal side of this process and the commissure of the optic nerves. The only vessels which it gives from its entrance into the foramen caroticum to the place where it perforates the dura mater are one or two small branches which perforate the petrous portion of the temporal bone, and pass to the cavity of the tympanum, and as it lies beside the cavernous sinus, two or three little twigs to the dura mater, pituitary gland, body of the sphenoid bone, and to the third, fourth, fifth, and sixth pairs of nerves which lie external to it and in contact with the outer or inner wall of the cavernous sinus.

The ophthalmic artery arises from the anterior side of the carotid while that vessel is passing into the dura mater, by the side of the anterior clinoid process; it enters the foramen opticum at first external and inferior to the optic nerve, over which it mounts obliquely towards its internal side, passing between it and the superior rectus muscle of the eye; it then directs its course along the superior and internal part of the orbit between the obliquus superior and rectus internus, towards the inner canthus of the eye where it terminates. Before entering the orbit it gives off a few small twigs to the dura mater and cavernous sinus, and within the orbit it furnishes the following branches:—1. the lachrymal; 2. the arteria centralis retinæ; 3. the supra-orbital; 4. the ciliary; 5. the muscular; 6. the ethmoidal; 7. the palpebral; 8. the frontal; and 9. the nasal.

The order in which these arteries arise from the ophthalmic presents many varieties; but they are constant in their distribution.

1. *The lachrymal artery* is one of the largest branches of the ophthalmic: it sometimes comes from the middle meningeal, and enters the orbit by the foramen lacerum orbitale of the sphenoid bone. It runs forwards between the external wall of the orbit and the rectus externus, giving branches to that muscle, the periosteum, levator palpebræ superioris and sheath of the optic nerve. One of its branches traverses the malar bone, and entering the temporal fossa anastomoses with the anterior deep temporal; another little branch frequently traversing this bone passes outwards through the same hole with the nervus subcutaneus malæ, and anastomoses with branches of the transversalis faciei. The continuation of the artery then divides into several branches which are distributed to the lachrymal gland and the external part of the upper eyelid, anastomosing with the palpebral and the temporal arteries.

2. *The central artery of the retina (arteria centralis retinæ)* penetrates the substance of the optic nerve to enter a canal in its centre, the porus opticus, in which it passes forwards, and is distributed to the retina, the vascular layer of which it forms by its ramifications.

3. *The supra-orbital* arises after the centralis retinæ, passes forwards along the superior wall of the orbit above the levator palpebræ superioris and superior rectus, giving branches to these muscles, the periosteum, and the sclerotic: on reaching the margin of the orbit, it passes out through the superciliary foramen, along with the frontal branch of the ophthalmic nerve, giving in its passage a branch which enters the substance of the frontal bone; this artery then mounts beneath the corrugator supercilii and orbicularis palpebrarum muscles, and is expended on these muscles, the occipito-frontalis and the integuments; it anastomoses with branches of the lachrymal and frontal.

4. *The ciliary arteries* sometimes amount in number to thirty or forty; they consist of three sets: the posterior or short, the long, and the anterior. The posterior ciliary arteries are very numerous, sometimes amounting in number to thirty or forty: although mostly arising from the ophthalmic, some of them come from the inferior muscular, the supra-orbital, posterior ethmoidal or lachrymal; they run along the optic nerve very tortuous, and entangled with the ciliary nerves, anastomosing freely with each other.

The posterior or short ciliary arteries pierce the sclerotic close to the entrance of the optic nerve; some of their branches are distributed to that membrane in which they anastomose with branches from the muscular arteries; while all the others advance nearly parallel, dividing at very acute angles into numerous smaller twigs; these branches are at first external to the choroid; but in their course forwards they penetrate to the internal surface of that membrane, and becoming more numerous from having undergone new subdivisions, form a network of anastomoses from which several branches are sent to the ciliary margin of the iris, where they anastomose with the anterior ciliary, but a greater number are given to the ciliary processes in the centre of which they form a very fine network, and finally end in a circle of anastomoses surrounding the margin of the circle in which these processes terminate internally.

The long ciliary arteries are two in number, one internal, the other external; they are larger than the short ciliary arteries among which they arise, but pierce the sclerotic obliquely at a greater distance from the optic nerve; they pass forwards between the sclerotic and choroid, and having arrived at the ciliary ligament, they divide each into two long branches which separate from each other at obtuse angles, and, coursing along the ciliary margin of the iris, form a circle around the greater circumference of that membrane which receives branches of anastomosis from the short ciliary arteries. From the interior of this circle numerous branches arise, each of which divides into two, which diverge at obtuse angles, and, anastomosing with each other and with the anterior ciliary, form another arterial circle within the former. Thus there are two arterial circles, one within the other at the greater circumference of the iris. From the concavity of this inner circle the arteries of the iris arise. These arteries are very numerous; they converge in serpentine lines towards the papillary margin of the iris, where they anastomose, in the manner of the mesenteric arteries, to form the lesser arterial circle of the iris. All these arteries, however, do not contribute to form this lesser arterial circle; a great number pass beyond it, and, along with the branches which arise from its concavity, advance towards the pupil. There are thus three arterial circles in the iris, two close together at its greater circumference or ciliary margin; the third much smaller, surrounding its pupillary margin, and communicating with the preceding by a radiation of branches situated on the anterior surface of the iris.

The anterior ciliary arteries are two or three in number; sometimes coming from the palpebral or from the branches which go to the recti muscles; they pass forward to the anterior part of the globe of the eye, where they each divide into many branches, the smaller of which are distributed to the conjunctiva and the sclerotica, the others pierce the sclerotica, near the circumference of the cornea, pass through the ciliary ligament, and join the arterial circles of the greater circumference of the iris; some passing beyond that circle go to the iris, and others are distributed to the anterior part of the choroid.

5. *The muscular arteries* generally consist of two, an inferior and a superior. The inferior muscular artery is a branch which is generally present; it sometimes gives off the centralis retinæ and one or more ciliary; it passes inwards to supply the inferior and internal recti muscles, and sends some branches into the nasal fossæ.

The superior muscular is less regular than the former; it passes forwards immediately under the superior wall of the orbit, and divides into many branches, which are distributed to the superior and internal recti, the superior oblique, the levator palpebræ superioris, the periosteum, and the sclerotic.

6. *The posterior ethmoidal artery* sometimes arises from the lachrymal or supra-orbital; it passes inwards between the superior oblique and rectus internus, and enters the foramen orbitarium internum posterius, giving branches to the anterior ethmoidal cells and their lining membrane; it then enters the cranium, where it is distributed to the dura mater, over the cribriform plate, through the holes of which it sends some branches to the pituitary membrane, and anastomoses with the anterior ethmoidal.

The anterior ethmoidal artery is given off by the ophthalmic towards the anterior part of the orbit; it passes through the foramen orbitarium internum anterius with the nasal branch of the ophthalmic nerve, and after giving branches to the interior of the frontal sinus and anterior ethmoidal cells, it enters the cranium and divides into many branches, some of which go to the dura mater, and others descend into the nasal fossæ by the holes in the cribriform plate of the ethmoid bone, and are distributed to the pituitary membrane.

7. *The palpebral arteries* sometimes arise by a common trunk and sometimes separately.

The superior palpebral arises a little further forward than the inferior; they are distributed to the conjunctiva and to the eyelids, in which they spread out their branches between the skin and the orbicularis muscle. They principally divide each into two branches, one of which runs along the tarsal margin, supplying the tarsal cartilage, Meibomian glands, and conjunctiva, and the other nearer to the base of the eyelids in an oblique course from within outwards.

The superior palpebral anastomoses with the lachrymal, superciliary, frontal, and anterior branch of the temporal.

The inferior palpebral anastomoses with the infra-orbital, the lachrymal, and nasal.

After the ophthalmic artery has given off the palpebral, it divides into two branches, one of which is the frontal and the other the nasal.

8. *The frontal artery* is usually the smaller of the two; it passes out of the orbit at the superior and internal part of the base of that cavity, and divides almost immediately into two or three branches, which ascend on the forehead, over which they ramify, and are distributed to the orbicularis, corrugator supercilii, pyramidalis nasi, and occipito-frontalis muscles, to the periosteum and common integuments: these anastomose with the opposite artery, the superciliary, and the temporal.

9. *The nasal artery* varies in size, being sometimes only a very trifling branch, which terminates at the root of the nose; sometimes its size is considerable, as, when it descends very low, contributing with the lateral nasal branch of the facial to supply the place of the dorsal artery of the nose, in which case it extends to the lower part of that organ; it always anastomoses with the facial and inferior palpebral, and gives branches to the integuments, cartilages, and bones of the nose, to the lachrymal sac, to the corrugator supercilii, and the internal part of the orbicularis palpebrarum.

The internal carotid, after it has furnished the ophthalmic artery, is distributed entirely to the brain, especially to its anterior part, the posterior part of that organ receiving its principal supply of blood from the vertebral. Having pierced the dura mater at the external side of the anterior clinoid process, and external to the optic nerve, the internal carotid artery gives several minute branches to this nerve, to the pituitary gland, the infundibulum, and anterior part of the brain; shortly after this it gives a branch which is very variable in size, frequently differing in this respect on opposite sides in the same subject; this is the *lateral or posterior communicating* branch of Willis, which passes backwards and a little inwards, external to the commissure of the optic nerves, infundibulum, tuber cinereum, and the corpora mammillaria, and joins the posterior artery of the cerebrum, which is a branch of the basilar: the motor oculi lies external to it. In its course it gives small branches to the corpora mammillaria, the crus cerebri, the optic nerves, and the choroid plexus.

After having given off the communicating artery, the carotid sends a branch to the choroid plexus, *the arteria choroidea;* the artery passes backwards and outwards, enters the tractus opticus, supplies the pia mater of the middle lobe of the brain and the optic thalamus, and, entering the inferior cornu of the lateral ventricle, spreads out its branches in the choroid plexus.

After having given off the choroid artery, the internal carotid divides always at an obtuse angle, and at the internal extremity of the fissure of Sylvius, into two branches, the anterior and the middle cerebral, of which the latter is much the larger vessel: sometimes the lateral communicating artery arises at the place of this division, and forms with these branches a sort of tripod.

The anterior cerebri, also called the artery of the corpus callosum, is always smaller than the media cerebri; it passes upwards, forwards, and inwards to the fissure which separates the anterior lobes of the cerebrum, passing over the optic nerves, and inferior to the internal origin of the olfactory: on entering the above-mentioned fissure, it approaches closely to the corresponding branch of the opposite side, with which it communicates by a large and very short transverse branch, called the anterior communicating artery, by which the circle of Willis is completed anteriorly: sometimes this branch is double, and occasionally we find it partially double, in consequence of a forking of one of its extremities; its place is sometimes supplied by a fasciculus of small branches; it gives off, especially when it is unusually long, a number of small twigs, which pass upwards and backwards to the septum lucidum, fornix, and corpus callosum.

From the place of this communication the trunk of the anterior cerebri passes forwards under the corpus callosum, giving off considerable branches to the inferior and internal part of the anterior lobe of the cerebrum; it then turns round to the anterior extremity of the corpus callosum, mounts up on the internal surface of the hemisphere of the cerebrum, and divides into many branches, the anterior and superior of which supply the convolutions on their internal surface, while the posterior take a lower course along the upper surface of the corpus callosum, at the posterior extremity of which they take an ascending direction. All these branches extend to the superior surface of the cerebrum, and anastomose with those of the media cerebri and the posterior cerebri, which is furnished by the vertebral.

Besides these large branches into which the arteria callosa divides superiorly, it gives off from its inferior and concave side a vast number of smaller branches, which penetrate the corpus callosum.

Sometimes, instead of being connected by the communicating branch, the anterior cerebral arteries of opposite sides unite, forming a single trunk, which runs forward for some little distance, and then divides into a right and left branch; this junction is the more remarkable, on account of its analogy to the union of the two vertebral arteries in forming the single trunk of the basilar on the median line.

The media cerebri, from its greater size compared with the anterior branch, appears, as it were, the continuation of the trunk of the carotid; it passes outwards and backwards, in the fissure of Sylvius, and divides into two branches, the subdivisions of both of which are distributed over the pia mater of the anterior and middle lobes of the brain, anastomosing in front with the anterior cerebri, and behind with the posterior cerebri from the basilar: this artery at first gives branches at the base of the brain to the pia mater on the crus cerebri; one of these, larger than the others, enters the inferior cornu of the lateral ventricle, where it is lost in the choroid plexus.

The anterior and middle cerebral arteries are not always similarly disposed on opposite sides; it not unfrequently happens, as Haller has remarked, that the two large trunks of the middle cerebral arteries are given off by the right carotid, and the two anterior from the left carotid, while the three others come from the right: considering these anomalies with that of the union of the two cerebral already mentioned, we here find a very remarkable repetition of many of the varieties exhibited by the mode in which the trunks that spring from the arch of the aorta take their origin.

For the BIBLIOGRAPHY, see that of ANATOMY (INTRODUCTION), and of ARTERY.

(J. Hart.)

The following observations are to be regarded as supplemental to the preceding article.

There is no fact more worthy of the attention of the practical surgeon, as regards the anatomical history of the carotid artery, than the free anastomosis which exists between the external and internal carotids of both sides at nearly all the stages of their course. This is especially the case with the external carotid arteries which anastomose at numerous short intervals from their origin to their termination, where they likewise communicate with some small ramifications of the internal carotids. Nor is the communication between the internal carotids less free, although it is less frequent: this communication is formed within the cranium at the anterior segment of the circle of Willis. Moreover, by means of the posterior communicating artery the internal carotid anastomoses with the posterior cerebral, and thereby with the subclavian, through the medium of the vertebral artery. And farther, by the anastomoses of the superior thyroid artery with the inferior, and of the occipital with the cervicalis ascendens, profunda, and vertebral, a communication is established between the external carotid artery and the subclavian.

From the knowledge of the communication thus existing between these several portions of the arterial system of the neck and head, we may deduce some very useful inferences.

1. It is evident that the carotids of both sides may be injected by even a coarse injection, from a pipe introduced into the artery of one side. This is a fact well known to every practical anatomist.

2. With the knowledge of this freedom of communication between the carotids, no surgeon will look for uniform success after the application of a ligature, in cases of wounds of either carotid or of one of its branches, if the ligature be applied only below the situation of the wound. Nevertheless, experience tells us, that such a plan of treatment has been successful in several instances; and it is worthy of notice that in almost all the successful cases the primitive carotid was tied very shortly after the infliction of the wound, at a time when the collateral branches could not have become sufficiently enlarged to admit of the full circulation in them; while, on the other hand, in two unsuccessful cases, the primitive carotid was not tied for some days after the receipt of the wound, and secondary hemorrhage ensued in each case.

3. The free anastomosis of the two internal carotids with each other and with the subclavians through the vertebrals within the cranium, sufficiently evinces that the circulation of the brain after the obliteration of either carotid, by ligature or otherwise, may be easily maintained; and experience fully confirms this inference from anatomy. That a disturbance of the cerebral circulation does occur occasionally after the operation of tying the carotid is fully proved; but it would appear that it is an occurrence much more rare than might, *à priori*, be expected. Of seventy cases, collected by Berard,* in which this operation was performed, symptoms arising from cerebral affection appeared only in a very few, and in two only of these instances the patients died from the effect produced upon the cerebral circulation. One of these cases occurred in the practice of Mr. Aston Key; the patient fell into a deep sleep after a severe fit of coughing, and died shortly afterwards without awaking. On examination it was found that the carotid of the opposite side was obliterated by a coagulum nearly as low as its origin from the aorta, so that the cerebral circulation could only have been maintained by the two vertebral arteries, which in this case were smaller than usual. In the second case, which was operated on by Langenbeck,† immediately after the application of the ligature the patient became motionless, with closed eyes, without speaking, except when addressed several times in succession; he sank gradually, and died in thirty-four hours after the operation.‡

In three of the cases collected by Berard, some disturbance or indistinctness of vision, on the same side as that on which the artery was tied, followed the operation; in one of these the impairment of sight was accompanied by syncope, and a sensation of cold affecting the whole of that side of the face; in a second, related by Mr. Mayo, the impaired vision was only on the right side, the carotid of which side had been tied, and the sense was perfectly restored in a few hours. In the third case one eye was completely deprived of sight, and the sense of hearing greatly weakened in the ear of the same side. Berard remarks that the loss or impairment of vision on one side is unfavourable to the opinion that such an occurrence is to be attributed to disturbed cerebral circulation; it is sufficiently accounted for by the fact that there is a considerable diminution in the quantity of blood sent to the eye; for that organ is supplied by a direct branch of the internal carotid, viz. the ophthalmic, which anastomoses at its termination with several of the terminal branches of the arteries of the face; and it is not improbable that in the cases above referred to, the branches which form this anastomosis, as well as those forming the circle of Willis at the base of the brain, were much smaller than usual.

In other cases hemiplegia, more or less general and perfect, followed the operations after a longer or shorter period. In a case related by Magendie, that of a young girl, in whom the *left* carotid was tied, there appeared on the sixth day paralysis of the *right* arm, of the pharynx and larynx, and numbness of the right lower extremity. The paralysis gradually diminished, but the intellect was so far impaired that the patient lost the power of reading.* In Sir A. Cooper's first case, the right arm and leg were deprived of sensation and in part of motion on the seventh day after the operation; and a man, in whom Mr. Vincent tied the right carotid for aneurism, was attacked with complete hemiplegia of the left side in half an hour after the operation, and continued in that state till his death on the seventh day. It is remarkable that, in all these cases, the paralysis was situated on the side opposite to that on which the artery was tied; a fact which alone would indicate that the cause of the paralysis was seated in the brain.

Aneurisms do not occur so frequently in the carotid arteries as in the aorta or in the large arteries of the extremities. They are most frequently found situated at the bifurcation of the common carotid, where also calcareous and atheromatous deposits are very often met with. In the lower part of the common carotid an aneurism is, of course, a more formidable disease than if it were situated high up, in consequence of the impossibility of applying a ligature between the artery and the heart. Sometimes an aneurism of the aorta projects upwards into the neck, compressing and obliterating the carotid, and simulating all the characters of aneurism of its lower portion. I am not aware that there is on record any instance of aneurism of the internal carotid artery in its cervical portion, although our museums are not without specimens of aneurismal dilatations of it after it has entered the cranium and as it lies by the side of the sella Turcica.

* Dict. de Médécine, art. *Carotide*.

† Arch. Gén. de Méd. t. xix. p. 118.

‡ Dr. Mussey, of New Hampshire, in America, has recorded a case in which he tied both primitive carotids within twelve days of each other, and without any untoward result. The reader will find the case quoted at length in Mr. Guthrie's valuable work on the Diseases and Injuries of Arteries, p. 350.

* Journal de Physiol. April, 1827.

We sometimes find the cervical portion of this artery in a tortuous state, but we rarely see in it those atheromatous and earthy deposits which are met with in other parts of it.

In the dead body there is no difficulty in exposing the common carotid artery in any part of its course, but during life much embarrassment is occasioned by the alternate dilatation and collapse of the internal jugular vein, corresponding with expiration and inspiration, and sometimes by some small veins which lie in front of the artery. It may be cut down upon either above or below the omohyoid muscle, but in the former situation the superficial position of the vessel and the less complexity of its relations render it more easy to be got at. In both situations the anterior margin of the sternomastoid muscle forms a useful guide to the artery; but much more careful dissection is required when the operation is done in the region below the omohyoid muscle. Here great care is demanded in dissecting back the sternomastoid muscle, and in drawing the sternothyroid inwards; the thyroid body and, on the left, the œsophagus must be avoided, and in passing the ligature round the artery, the operator must take care to avoid not only the vein and par vagum but also the inferior thyroid artery, the recurrent and sympathetic nerves and the cardiac branches of the latter, and on the left side the thoracic duct. As anomalies in the distribution of some of the arteries in the neck are occasionally met with, the surgeon should be on his guard against such an occurrence, especially in operating in the low region where they are most likely to be met with. Two arteries may be found here occupying pretty nearly the situation of the carotid artery. One of these will be the carotid itself, the other the vertebral, which sometimes passes high up in the neck in front of the rectus capitus anticus muscle, before it enters the canal in the transverse processes of the cervical vertebræ. In a case related by Mr. Allan Burns,* the vertebral artery entered this canal only a few lines below the bifurcation of the carotid, and in its passage up the neck, parallel to and behind the carotid, it was separated from that vessel only by its sheath. A low bifurcation of the carotid artery would be equally likely to occasion embarrassment; and the possibility of such a condition of the cervical vessels as well as of the anomalous course of the vertebral artery before alluded to are strong arguments in favour of the recommendation of Mr. Burns, that, "when the surgeon has reached the sheath of the vessels he ought uniformly, before opening it, to press the carotid between the finger and thumb. If the pulsation of the tumour be not in this way controlled, he will do well to pause before he pass a ligature round that vessel."† In fine we sometimes find the inferior thyroid artery crossing in front of the common carotid in the inferior region.

* Surgical Anatomy of the Head and Neck, p. 170.

† Loc. cit.

It is very easy in the dead body to find the primitive carotid low down in the neck by cutting in the cellular interval between the clavicular and sternal portions of the sternomastoid muscle, but it is not so easy to pass a ligature round it; and this difficulty is greatly magnified in the living subject, in consequence of the necessarily limited space in which the operator has to work; the difficulty too is greatly increased by the contractions of the sternomastoid muscle.

To expose the external carotid artery shortly after its origin, it is only requisite to follow the same steps as are necessary for cutting down on the common carotid above the omohyoid muscle. It is in general advisable to apply the ligature below the point at which the digastric muscle crosses the artery and below the origin of the superior thyroid. Some embarrassment is likely to result from the plexus of veins which in this region often lies in front and on the sides of the artery. A ligature, however, may be passed round this artery above the digastric muscle, but it will be requisite that the external incision shall commence higher up. The needle must be passed between the parotid gland and the digastric tendon, the distances between these parts having been previously increased by drawing down the tendon of the muscle.

(R. B. Todd.)

CARTILAGE (Lat. *cartilago*, quasi *carnilago;* Gr. χονδρος; Fr. *cartilage;* Germ. *Knorpel;* Ital. *cartilagine*) is a firm elastic substance, of pearly whiteness, and uniform or homogeneous in its appearance. It bears a considerable analogy to bone, and is to be found in situations where less rigidity and more elasticity are required than the osseous system presents.

Several tissues, differing a good deal from each other, were formerly comprehended under this term. These have been variously classified by modern anatomists; but the division of them into *cartilages* and *fibro-cartilages*, proposed by Bichat,* is that which is now generally adopted. Although Bichat was happy in the choice of names for these tissues, yet, in arranging the individual pieces under the two heads just mentioned, he has not been found quite correct. Some of the true cartilages are placed by him amongst the fibro-cartilages, an error which Meckel perceived and rectified.†

Cartilages may be divided into the *temporary*, the *permanent*, and the *accidental*.

A. The TEMPORARY cartilages are substitutes for bone in the earlier periods of life, and after a certain time become ossified. We find them at birth forming the extremities and larger eminences of long bones, a great part of the short bones, and the margins of the broad ones. These gradually disappear, and at puberty cease to exist. It is unnecessary to say more of them here. (See OSTEOGENY.)

B. PERMANENT cartilages are met with under

* Anatomie Générale, tom. iii. Par. 1812.

† Manuel d'Anatomie, tom. i. Par. 1825.

two forms: 1, the *articular*, attached to bone, and entering into the formation of joints; 2, the *non-articular*, forming canals more or less perfectly.

I. The *articular* cartilages are called *diarthrodial, obducent*, or of *incrustation*, when they belong to the moveable articulations; *synarthrodial* when connected with those very limited in their motions, or the immoveable articulations of some authors. We think it unnecessary to do more than refer to these cartilages here, as their characters will be found fully described in the article ARTICULATION.

II. The *non-articular* cartilages are usually much more flexible than the articular. In some cases they are attached to bones, and lengthen them out, as the preceding class. Of this we see examples in the nose, the auditory canal, and the Eustachian tube. In other cases they are insulated, forming the basis of distinct organs, as the larynx, the trachea, the eyelids. All the cartilages of this class have a well-marked perichondrium.* Some of them, as the epiglottis, the tarsal cartilages, and those of the alæ nasi, are so thin, so flexible, and assume so much of a fibrous appearance from their perichondrium, that Bichat placed them amongst the fibro-cartilages; but these last never have perichondrium, and their fibrous texture is distinctly independent of their investment, as is easily seen without any preparation. (See FIBRO-CARTILAGE.)

The *structure* of non-articular cartilage, like the other forms, may, by protracted maceration, be shown to be fibrous; but the arrangement of its fibres is different; they interlace a good deal more.

The *physical properties* of cartilages are such as to fit them admirably for the functions which they have to perform. They are solid, resisting, and incapable of extension, that they may be able to preserve the form of certain parts as effectually as bone; and they are flexible and elastic, to enable them to yield in some degree, and immediately to resume their original shape.

Elasticity is the property most essential to them, and on this their usefulness mainly depends. Its existence is easily demonstrated. If the blade of a knife be pressed into a diarthrodial cartilage, the reaction of the displaced fibres expels it with force; and a piece of any cartilage, if bent between the fingers, returns with a spring to its former shape. The elastic fibres of diarthrodial cartilage are so placed as to receive impressions on their extremities; they yield a little to force, and only a little, else the ligaments would be too much relaxed; but they yield enough to let the opposite surfaces accommodate themselves to each other, and to deaden the shocks which would otherwise have an injurious effect on the nervous centre. In fact, these articular cartilages serve as a series of springs between the ground and the delicate organs which they support. The elasticity of the costal cartilages is obvious and essential. They are subject to torsion in the act of inspiration, and by their reaction become an important agent in expiration.

Differences depending upon age.—Cartilages are soft, transparent, and like jelly in the very young fœtus. Gradually, as the individual advances to maturity, they become opaque, white, firm, and elastic; and in the adult these qualities are in their greatest perfection. In old age they lose again their elasticity and flexibility; a yellowish colour takes the place of their beautiful pearly white; they become dry and brittle, and shew a great tendency to ossify.

Organization. — Cartilage appears at first sight to be perfectly homogeneous throughout, like a concrete jelly, not shewing any traces of organization, nor exhibiting the least appearance of vessels. But, as an attentive examination proved it to be fibrous, so we shall be able to satisfy ourselves that it possesses an organization similar to other parts of the living system. In healthy cartilage, it is true, no red vessels can be demonstrated, neither can the finest injection be made to penetrate it, nor will madder used in food colour it. But disease sometimes shows red vessels ramifying through its substance;* and several other phenomena lead us to the conviction that it is at all times permeated with vessels, though they may be too fine to admit the red globules. For instance, we find cartilage assume a yellow tinge in jaundice. If we slice off a bit, the dry surface is soon moistened with a serous fluid, which, doubtless, comes from its colourless vessels. Exposed cartilages have been known to granulate, which implies the existence of vessels, and perhaps of cellular substance. And we know that in the old and laborious there is often not the least sign of wear, although the enamel of the teeth be quite worn away. Where a perichondrium is present, we may suppose the vessels first ramify in it before they enter the cartilage. Dr. William Hunter describes the arrangement of the vessels which supply diarthrodial cartilage to be very peculiar. He says, "All around the neck of the bone there are a great number of arteries and veins which ramify into smaller branches, and communicate with one another by frequent anastomoses, like those of the mesentery. This might be called the *circulus articuli vasculosus*, the vascular border of the joint. The small branches divide into still smaller ones upon the adjoining surface, in their progress towards the centre of the cartilage. We are seldom able to trace them into its substance, because they terminate abruptly at the edge of the cartilage, like the vessels of the *albuginea oculi* when they come to the cornea."†

It does not appear that nerves or absorbents have ever been traced into cartilages; but the phenomena of disease, pain, ulceration, &c., convince us that they are supplied with both. Even in their healthy condition, though their

* If we except the capsule of the lens and the posterior layer of the cornea, supposing these structures to belong to the cartilaginous system. See EYE.

* Brodie on Diseases of Joints, p. 183, third edition.

† Phil. Trans. 1743.

animal sensibility is exceedingly low, scarcely perceptible, yet it probably does exist, and will manifest itself whenever any cause is operating upon them which might destroy their texture. We may, indeed, cut an exposed cartilage without pain, and the violent pressure it undergoes in a sound joint is unheeded. But the former is a kind of injury from which cartilage may be said to be totally exempted, and the latter is that for which it is peculiarly adapted. In either case sensibility would be useless or inconvenient. Let but a foreign body however get into a joint, between its cartilages, such as might disorganize them, and then an alarm is set up too great to be attributed to the synovial membrane alone, and depending, we may suppose, in part at least, on the cartilage itself.

C. Accidental cartilage.—By this name we designate the cartilaginous concretions which are occasionally found in situations where they do not ordinarily exist. They present themselves in several organs, under various forms, and in different stages of development. Laennec divides them into *perfect* and *imperfect;** but it is not easy to point out any line of distinction between these two classes; they differ only in degree, the one passing gradually into the other as its development becomes more complete. We rarely, indeed, meet with accidental cartilage which deserves to be called *perfect;* in one part it is fibrous, or of a dense cellular nature, in another it is cartilaginous, while a third portion of the same piece is passing into the osseous state.

The forms and situations in which they occur, will permit an arrangement of them under three heads:—

1. The *insulated* or *loose* cartilages, which are found either (*a*) in joints or (*b*) in serous sacs.

a. Those of the joints are rounded or ovoid, usually flattened, sometimes lobulated, always smooth, polished, and lubricated with synovia, frequently osseous in their centre. They vary in magnitude from the size of a mustard-seed to that of an almond; and in one instance Mr. S. Cooper found in the knee a concretion of this kind, which was as large as the patella. They also vary considerably in numbers; Haller saw twenty in the articulations of the lower jaw, and Morgagni met with twenty-five in a knee-joint. Their most usual seat is in the knee, but they have been found in the hip, jaw, elbow, and wrist. They are commonly "loose," moving freely in the cavity, but sometimes connected to the synovial sac by slender membranous attachments.

With respect to the *origin* of these bodies various opinions have been entertained. Haller and Reimarus supposed that they were fragments of the original cartilage, accidentally detached. Cruveilhier found fifteen of them in a hip-joint some years after it had been injured, and conceived that he saw an exact correspondence between them and certain depressions in the cartilages of that articulation. Bichat conjectured they might be altered portions of the synovial membrane. According to John Hunter, they may have had their origin in a coagulum of blood poured into the joint from an injured vessel, and there becoming organized. This coagulum would, he thought, assume, as in all other situations, the peculiar organization of the parts in its immediate vicinity. Laennec and Beclard were of opinion that they might be formed outside the synovial membrane, and push it before them so as to form a pedicle, which in some cases remained, but more generally was ruptured. This opinion Laennec supported by observations made on similar substances in serous sacs, where he traced them through all the degrees of their development, from the incipient stage, in which they formed a slight projection behind the membrane, to the period when they became perfectly isolated bodies. Sir Benjamin Brodie, whose authority on this subject is of so much weight, remarks, "It is generally supposed that these loose bodies have their origin in coagulated lymph which has been effused from inflammation of the inner surface of the synovial membrane, and which has afterwards become vascular. In the majority of cases, however, which I have met with, no symptoms of inflammation preceded their formation; and hence it is probable that, in some instances, they are generated like other tumours, in consequence of some morbid action of a different nature. They appear to be situated originally either on the external surface, or in the substance, of the synovial membrane; since, before they have become detached, a thin layer of this latter may be traced to be reflected over them."*

When inflammation is of long standing in a *bursa mucosa*, it is not unusual to find in it a number of loose bodies, of a flattened oval form, and of a light brown colour, with smooth surfaces, resembling small melon-seeds in appearance. There seems to be no doubt that these bodies have had their origin in the coagulated lymph effused in the early stage of the disease.† From the resemblance which these concretions bear to loose cartilages, we might infer that they both have had a similar origin; but, as there can be no doubt that loose cartilages sometimes begin to be formed outside the synovial membrane, we must not conclude that this is the only mode.

From the evidence before us, therefore, and from observations made on the second species of accidental cartilage, to be mentioned by-and-bye, we are inclined to admit two distinct sources from which these loose cartilages may have commenced. One, a deposit in the cellular tissue outside the synovial membrane; the other a deposit within this membrane. The origin of both being lymph, which becomes cartilaginous, and often proceeds to an osseous state.

b. Insulated cartilages are sometimes found in connexion with true serous cavities. They are seldom larger than a pea, rounded, floating, or attached by a pedicle to the inside of the

* Dict. des Sciences Méd.

* Pathological and Surgical Diseases of the Joints. Lond. 1834.

† Idem.

sac, and, in some instances, distinctly outside it. Laennec often found them between the tunica vaginalis testis and the tunica albuginea, and on one occasion in the lining membrane of the lateral ventricles of the brain. Andral saw three of these bodies in the serous membrane of the brain; one of them floated loose and unattached in the sac of the arachnoid; the other two were attached to the choroid plexus by a delicate cellulo-vascular prolongation. He also often found them in the peritoneum, sometimes perfectly isolated, at other times appended to the serous membrane.*

2. Accidental *cartilages of incrustation*, occurring in plates, are very irregular in size and shape. They are most frequently found in fibro-serous membranes, as the dura mater, the pericardium, and the immediate coverings of the testis and spleen. Upon this last viscus they are seen more frequently than in any other situation whatsoever. Bichat supposed they were altered portions of the fibrous membrane, having so generally met with them where the latter existed. The subserous cellular tissue is the proper seat of them. We often find them between the middle and internal coats of arteries, in what may likewise be called a subserous cellular tissue. (See Artery.)

It is exceedingly rare to meet with them under mucous membranes. Andral saw one solitary instance of a true cartilaginous mass developed in the submucous cellular tissue of the stomach. The subcutaneous cellular substance is likewise nearly exempt from them; but the same experienced pathologist relates, that one of the lower extremities of a woman who died in *La Charité* in the year 1820, was affected with elephantiasis; underneath the skin, and occupying the place of the muscles, which were reduced to a few pale fibres, was found an enormous mass of condensed hard cellular tissue, possessing, in many places, all the physical characters of cartilage. In all these instances there is every reason to believe, from the closest examination, that the newly formed substance is developed at the expense of the cellular tissue alone, and that neither the fibrous nor the serous membranes are altered, nor indeed any adjoining texture. These last seem to be replaced by the accidental formation, but they are only absorbed to make room for it, and not transformed into the new substance. An exception must, perhaps, be made in favour of mucous membrane, which appears capable of undergoing this change. Laennec relates the case of a child, in the membranous portion of whose urethra he found a large calculus. The mucous membrane of the part presented several patches, of the size and thickness of a man's nail, which appeared to him semi-cartilaginous, and were incorporated with, and formed part of, the mucous membrane. In like manner Beclard found the mucous membrane of the vagina, in a case of prolapsus uteri, studded over with cartilaginous spots; and he observed a similar appearance on the prepuce of an old man, who had had phymosis from the time of birth.

What is the cause of these formations? Most probably they have their commencement in some obscure inflammatory action. It is true we often find them where there is no other appreciable lesion whatsoever, nor any trace of inflammation in the neighbourhood; but, on the other hand, they seem to be but a step removed, in structure, from coagulable lymph, and are sometimes imbedded in it; and the irritation and consequent inflammation produced by foreign bodies must be allowed to have occasioned them in the instances just related from Bichat and Beclard.

3. The *irregular* or amorphous masses which we sometimes see in the thyroid gland, ovaries, uterus, testes, brain, liver, lungs, spleen, kidneys, and heart, are supposed to differ from the preceding classes, not only in form, but in connexions and origin. They appear to be united by continuity of substance with the tissues in which they are developed, and, in fact, to be altered portions of them. But it is by no means proved that cellular tissue may not, even in these cases, be the nidus of such concretions, and that the organs have not rather been absorbed to make room for them, than transformed into them.

In false articulations, old cicatrices of the liver, lungs, &c., we find a substance resembling cartilage; but its description belongs to "*Fibro-cartilage*," to which we refer.

Chemical composition.—On this subject there is some difference among writers; Dr. Davy* found *diarthrodial* cartilage to consist of

Albumen	44·5
Water	55·0
Phosphate of lime	00 5
	100·0

Berzelius professes his ignorance of its composition. Neither diarthrodial nor non-articular cartilage yielded gelatine, and he doubts "whether the mass which constitutes them be of a peculiar nature, or similar to what we find in the fibrous coat of arteries."† By boiling *costal* and *synarthrodial* cartilages, gelatine is developed. He looks on them to be imperfectly developed bone, and to have the composition of its animal part, with the addition of 3·402 per cent of earth in the false ribs of a man of twenty.

In 100 parts of this earth he gives the following analysis from Frommherz and Gugert:

Carbonate of soda	35 068
Sulphate of soda......	24·241
Muriate of soda	8·231
Phosphate of soda	0·925
Sulphate of potass	1·200
Carbonate of lime	18·372
Phosphate of lime	4·056
Phosphate of magnesia .	6·903
Oxyde of iron, and loss.	0·999
	100·000

* Andral's Pathological Anatomy, translated by Townsend and West.

* Monro's Elements of Anatomy, vol. i.

† Traité de Chimie, tom. vii. Par. 1833.

Pathological conditions.—Cartilages are not subject to many diseases. Inflammation, ulceration, and ossification are almost the only ones to which they are liable; and of these the first is very indistinctly marked; the last scarcely deserves to be called disease. Cartilages are supposed to owe this exemption from morbid actions to their extremely low degree of vitality. Destitute of red vessels, and supplied with no more nervous influence than is barely sufficient to constitute them a part of the living system, they escape those changes to which highly organized parts are exposed; and, were it not for their connexion with more delicate and excitable tissues, their exemption would be still more complete. Some eminent pathologists have gone so far as to consider them incapable of any morbid action; especially the diarthrodial cartilages. "*Les cartilages diarthrodiaux ne jouissent point de la vie*," says Cruveilhier, who asserts that he could not excite disease in them by any of his experiments; and that he saw them perfectly sound in the midst of every other diseased structure. Mr. Key* also seems to allow them very little vitality in health, and to consider them very nearly passive in what are called their diseases.

Inflammation is rarely to be met with. Its characters are so slightly marked in *diarthrodial* cartilage, that we infer its existence, not so much from the signs which are present, as from observing that ulceration is a common occurrence—a state which we suppose to have been preceded by inflammation. The only marks of inflammation to be seen, even when most developed, are a softening of the cartilage, and in two instances detailed by Sir B. Brodie, vessels injected with red blood could be traced extending from the bones into the cartilages covering them. Severe pain accompanies this disease; but, as in all the cases on record, ulceration, or some other disease was also present, it cannot be determined how much of the pain belonged exclusively to it. The costal cartilages are subject to painful affections which usually occur in patients who have had syphilis, or to whom mercury has been administered injudiciously. These depend on inflammation of the perichondrium. They may terminate in ulceration or in osseous deposition, and have a close resemblance to periostitis.

Ulceration of cartilage is a very common occurrence in joints, but is extremely rare in other situations. It may be met with at any period of life, or in any articulation, but it is in the hip and knee we most frequently find it, and in persons who have passed the age of puberty and are under thirty or thirty-five. A striking peculiarity attends this affection, namely, that the formation of pus is by no means a constant accompaniment. The form and situations of ulcers in diarthrodial cartilages are very various. Sometimes they are small and deep; sometimes very superficial, like an abrasion—at one time attacking the free, at another the attached surface; and may commence in the centre or at the circumference. These ulcers may be divided into *primary* and *secondary*, the former arising independently of any disease in the adjoining tissues, the latter being preceded by a morbid state of the bone or synovial membrane.

The *primary* ulcer commences towards the centre of the cartilage, and always on its free surface. It is accompanied with much pain, but when exposed to view exhibits no sign of inflammation. There is no vascularity to be observed, no granulations, frequently no pus, nor any unhealthy appearance of the synovial membrane. Should the ulcer, however, have extended itself quite through the cartilage to the bone, the latter usually becomes carious, pus is secreted abundantly, and the synovial membrane sympathizes. The surface of the ulcer differs very much in different cases; in some it appears smooth, and of the colour of healthy cartilage, as if a portion were chiselled out. In others, and more generally, it is a little yellowish, dull looking, and slightly irregular. The edges are often irregular, never elevated nor undermined. The ulceration sometimes spreads superficially over a large extent; at other times it is small and deep, or it may destroy all the cartilage and expose the bone, which will also be found diseased. Most generally the remaining cartilage, if any, retains its healthy structure to the very edge of the absorbed portion.

Another appearance is often observed; a part of the cartilage is reduced to a fibrous state, the fibres being attached at one extremity to the bone, while at the other they are free, and have no lateral connexion. This condition of cartilage is said, by Sir B. Brodie, to be frequently, but not constantly, the first stage of ulceration; and he conceives it may often exist where no ulceration is ever to follow. Mr. Key looks on it as "a disease of a peculiar character." And we have frequently found it in the dissecting room, where there was not the slightest mark externally or internally of any other morbid action. The writer has observed it oftener on the patella than elsewhere; and as this is so seldom the part first involved in the ulcerative process, it probably depends on an action of a different nature. The writer has also seen it oftener in joints long dead than in the more recent, and has therefore thought it might possibly be caused, in some cases at least, by the action of the synovial fluid, or by decomposition.

Secondary ulceration may commence in the bone or in the synovial membrane. (*a*) When the bone is previously diseased, that side of the cartilage which was turned to it is first affected. The adhesion of the two tissues is diminished; we find it more easy to separate them. After some time a separation actually takes place, and a vascular net-work, sometimes a layer of granulations, occupies the interval. The surrounding cartilage is softened. The ulcer, with characters differing little from the primary form, goes on more or less rapidly, until an opening is made quite through into the cavity of the joint. When this opening is effected, the matter, which in this form of ulcer is always pre-

* Medico-Chirurgical Transactions, vol. xviii.

sent, finds its way into the synovial sac, and excites inflammation there.

The disease of the bone commonly giving rise to this ulcer is the slow strumous affection of the spongy extremities, so accurately described by Sir B. Brodie, the symptoms of which are familiar to every surgeon. A more acute inflammation of the osseous tissue is occasionally to be seen, and may be followed by a disease of the same nature, or differing only in the quickness of the course it pursues.

(*b*) Secondary inflammation extending from the synovial membrane is most apt to attack the edges of the cartilages in the first instance. These are thinned, as if abraded, and overlapped by the vascular or disorganized membrane. The bone remains sound, as in the primary ulceration. For further particulars on the ulceration of cartilage, see JOINT.

Does fractured cartilage ever unite by cartilage? It probably never does. The costal cartilages, when broken, unite by lymph, which soon after is converted in bone, but never appears to form true cartilage. When a fracture extends into a joint, as we often see in the condyles of the humerus and femur, the divided cartilage is united by a cicatrix, which is not truly cartilaginous. Neither does it appear that cartilage is ever regenerated. Laennec believed it was: "in examining a knee-joint, he found in the centre of the articulating surfaces, in place of the natural cartilage, a thin cartilaginous lamina, semitransparent, adherent to the bone; the old cartilage formed around it a projecting border, as if fimbriated."*

This observation certainly was not enough to establish its power of regeneration. We often find in cases of gout and rheumatism, and especially in the disease designated *morbus coxæ senilis*, that the cartilage is removed, and in its place a compact shining layer of osseous substance like ivory deposited. This is not owing to an ossification of the cartilage, for the cartilage is often found completely absorbed, and the rough bone exposed, which, if seen at a later period, would doubtless be covered with this deposit to prevent the disintegration of its cancellated structure.

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(Charles Benson.)

* Op. cit. p. 240.

CAVITY, in anatomy, (*cavitas;* Fr. *cavité;* Germ. *Höhle;* Ital. *cavita.*)—This term is used, in anatomy, to signify any excavation or even depression of more than ordinary depth, which may exist in or between solid parts. Hence we find cavities existing in bones, or formed by the junction of one or more bones, which, as they are severally destined for articulation with other bones, or for the reception or transmission of certain tendons, vessels, &c. are designated *articular* or *non-articular*. (See BONE.)

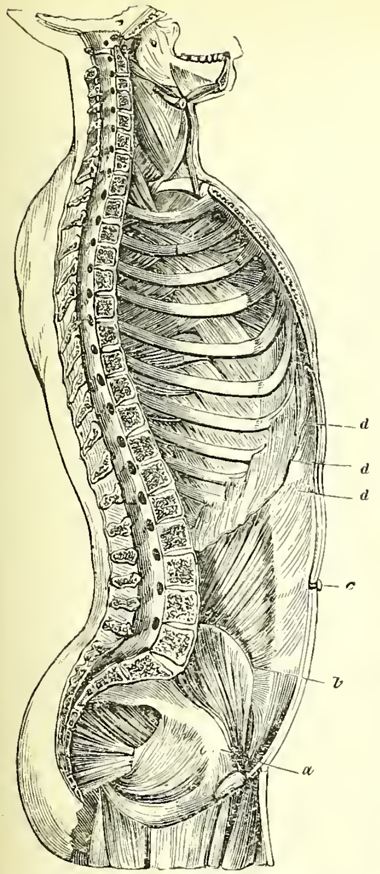
But we have likewise large excavations whose walls are of a more complicated arrangement, and which are destined to receive and protect those organs which are concerned in the functions of innervation, respiration, and digestion, and throughout a large proportion of the classes composing the animal kingdom are three in number, namely, the CEPHALIC or CRANIAL cavity, containing the brain—the THORACIC cavity, containing the organs of respiration—and the ABDOMINAL cavity, containing the organs of digestion and of the secretion of urine. To this last is appended, as a continuation, the PELVIC cavity, which is chiefly devoted to the organs of generation, as well as to some of those connected with the urinary excretion. We refer for particulars connected with the other cavities to the articles CRANIUM, THORAX, and PELVIS, and proceed to consider succinctly the anatomy of the ABDOMINAL CAVITY in its *Normal* as well as *Abnormal* conditions.*

ABDOMINAL CAVITY, (in human anatomy.)

The annexed woodcut exhibits a vertical section of the body intended to show the thoracic and abdominal cavities, from which the viscera have been removed. A simple reference to it and to *fig.* 204 will sufficiently explain the form and boundaries of the latter cavity, which have been already fully described in the article ABDOMEN. Our object in the present article is to examine the abdominal cavity as it is brought under the eye of the anatomist, when its contents have been exposed by removing or cutting through the abdominal parietes.

* Some anatomists object to the use of the term cavity, because, say they, every hollow in the animal body is full. Such an objection, on the principle of nature's abhorrence of a vacuum, would go to discard the use of the term, even from ordinary discourse. Considering the word in reference to its etymology, it is synonymous with excavation, which in no way implies emptiness, and it is in this sense that we must employ it in anatomical description. I apprehend that confusion has arisen from employing the same word to denote the excavation bounded by bone or by bone and muscle, in which the viscus or viscera are lodged, and to indicate the bag or sac of the serous membrane by which each of the three great cavities is lined. In this latter sense, the term cavity is certainly not appropriate, at least it may be most advantageously laid aside; and we can use, without the same risk of confusion, the expression bag or sac of the peritoneum, pleura, &c.

Fig. 203.

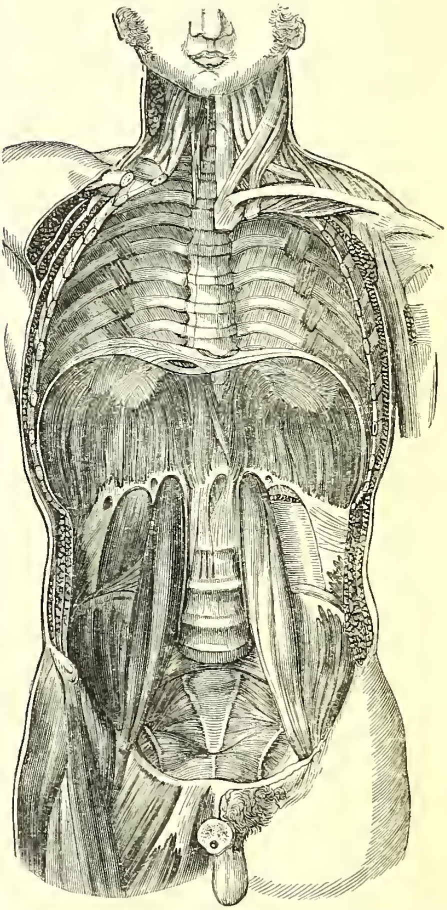


It rarely happens that we meet with an instance in which the abdominal viscera have not been more or less disturbed after death from their natural relations to one another. During life the contractile walls of the abdomen, ever active, maintain such a uniform degree of pressure on the contained organs, that displacements or alterations of positions are very rare occurrences excepting through some preternatural opening in the abdominal parietes. It is advisable to study the positions of the contents of the abdomen in a body recently dead, and which has not experienced any degree of disturbance.

When the anterior wall of the abdomen has been removed or freely laid open by a crucial incision, the contents of the cavity are brought into view in the following order: —

In the right hypochondriac region the liver projects to a slight extent below the inferior border of the chest. This, however, is not to be regarded as the position of the liver during life; the descent of that organ from behind the shelter of the ribs is attributable to its gravitation in consequence of the removal of the support which it obtained from the pressure of the anterior abdominal wall. The liver will thus be found to extend more or less into the proper epigastric region, covering and concealing the lesser curvature of the stomach with the gastro-hepatic omentum and the anterior, or more correctly, the antero-superior surface of the stomach to a variable extent. In this region we likewise see, corresponding pretty nearly to the cartilage of the ninth rib, the fundus of the gall-bladder in some instances completely covered by the liver, in others projecting beyond it or only covered by a duplicature of serous membrane which fills up a natural notch in the liver. In the epigas-

Fig. 204.



trium more or less of the stomach is seen, its greater curvature projecting forwards, having pendent from it the middle portion of the great omentum; and the left hypochondrium often (especially when the stomach is full) seems to be wholly occupied by the splenic extremity of the stomach, immediately below which there is a portion of the transverse colon, just where it is forming an angle with the descending colon. Sometimes the anterior margin of the spleen projects before it, and sometimes a still greater portion of the spleen is visible, if that organ be in a state of turgescence. Along the inferior boundary of the epigastric region, and projecting partly into that region and partly into the umbilical below, the transverse arch of the colon runs with a slight curve concave backwards and downwards. The position of this important portion of the great intestine is always lower in the abdomen of a subject thus opened than it can possibly be during life. In fact, when the abdominal wall is unimpaired and the usual compression is maintained, the stomach and colon must be in very close apposition with each other, so that it must be difficult, if not impossible, to make pressure from without on the one without affecting the other nearly to the same degree. The arch of the colon is loosely covered on its anterior surface by two laminæ of peritoneum, which descend from the greater curvature of the stomach and entering into the umbilical region are reflected upwards after a descent as far as the lowest part of that region, forming a curtain which covers the convolutions of the small intestine beneath the transverse arch of the colon. This curtain is the great Omentum or Epiploon, (*Omentum majus,*) which, in the natural condition of the parts during life, there is every reason to believe is closely applied to the anterior surface of the small intestine; much variety, however, may be observed as to the extent of its relation to this portion of the intestinal canal, and it is difficult to account for this variety. Thus we sometimes find the intestine uniformly covered by this membrane more or less loaded with fat, descending as low as the upper outlet of the pelvis; this may be regarded as the normal state in the adult. But at other times we find the omentum so crumpled up or contracted, that the small intestine is completely exposed, and it is only by pulling down the omentum from the arch of the colon towards which it is folded up or crumpled, that we can form an estimate of its extent. Again, in other cases we observe that it is only long enough to descend halfway or a little lower over the surface of the small intestine. It is said to have less extent in females who have borne many children than in any others; I cannot confirm this statement, inasmuch as I have not unfrequently seen it of its full dimensions in such subjects. In the natural state of the parts, then, the whole of the central portion of the umbilical region is occupied by the omentum, forming a moveable curtain over the anterior surface of the convolutions of the jejunum and ilium.

The iliac region of the right side is occupied by the cœcum or caput coli, and in the lumbar region of the same side the ascending colon is visible, sometimes when distended projecting considerably, at other times so contracted as to appear sunk towards the posterior wall of this region, and to allow of being overlapped and concealed from view by some of the convolutions of the small intestine. In the corresponding regions of the left side the remaining portions of the colon are seen, and they too are very frequently, if not generally, closely applied to the posterior wall: in the lumbar region the descending colon is much more frequently in a contracted than in a distended state, and in the iliac region, not occupying it to the same extent as its fellow is occupied by the cœcum, we find the sigmoid flexure of the colon winding its curved course over the psoas muscle, and sinking into the pelvis to assume the name of rectum. The lower convolutions of the small intestine invariably fill up the superior outlet of the pelvis, and are found to a greater or less extent in that cavity, in proportion as the bladder and rectum are empty or the reverse.

Such being the position of the parts as they appear when the anatomist lays open the abdomen in a recent subject, we proceed now to examine what parts are found in each compartment of this cavity, and the relation which they bear to each other. We may observe, in passing, that there cannot be *much* difference in the position of the abdominal organs during life, even in the varied attitudes of the body, from that which we find them to possess in a body recently dead. Making allowance for the pressure which is maintained upon them by the abdominal parietes, it is obvious that the position of each organ during life will be higher in the abdomen than that which it occupies in the dead body; all the organs are more firmly applied to one another and to the posterior wall of the abdomen.

It is not, however, unimportant to bear in mind that such is the nature of the contents of the hollow abdominal viscera, and such the rapidity with which they become accumulated, that changes of relation may be rapidly effected. Thus the stomach, or any part of the intestinal canal, may by a rapid accumulation of air or any other matter within it, occupy a much more extensive portion of the abdomen than it usually does in the natural state. This is allowed by the extraordinary compressibility of the other viscera, a compressibility which is every day exemplified in pregnancy, aud in cases of ovarian dropsy, of ascites, &c.

1. *The epigastric region.*—The right extremity of this region or the right hypochondrium is occupied almost entirely by the liver, which is connected with the diaphragm and anterior wall of the abdomen by the folds of peritoneum which form what are called the ligaments of the liver. When the left lobe of the liver is raised up, we see the lesser or gastro-hepatic omentum extended between the lesser curvature of the stomach and the transverse fissure of the liver. A defined margin terminates the gastro-hepatic omentum on the right side, just adjoining the neck of the gall-bladder: if the finger be pushed underneath this margin from right to left, it passes through an opening which leads into the cavity of the omentum, and if continued downwards behind the stomach will separate the laminæ of the great omentum. This opening is commonly known under the name of the *Foramen of Winslow*: the lesser omentum bounds it in front, behind it lie the supra-renal capsule, the vena cava ascendens, and the psoas muscle, covered by a lamina of peritoneum which ascends towards the diaphragm.

after having partly covered the duodenum.* The lesser splanchnic nerve will also be found in this situation lying on the quadratus lumborum muscle and on the psoas, and descending to throw itself into the renal plexus. On a plane posterior to the lesser omentum the inferior surface of the liver is in contact with the kidney, and with the angle of junction of the ascending and transverse portions of the colon, as is proved by the frequent adhesion of this intestine to the liver. The situation of the gall-bladder in this region demands attention;—its fundus corresponds to the cartilage of the ninth rib, beneath which it sometimes projects to an extent proportionate to the degree to which it is distended; hence it is evident that an unusually distended gall-bladder is not unlikely to form a tumour below the margin of the ribs presenting all the characters of an hepatic abscess.† The gall-bladder is, in this region, in close connexion either by its neck or body, with the duodenum or tranverse colon, a fact which explains the evacuation of gall-stones into either of those intestines. The left lobe of the liver projects more or less into the central portion of the epigastric region, or that which is called the proper epigastrium. Here it is in contact by its concave surface with the anterior superior surface of the pyloric half or third of the stomach. This latter viscus when contracted lies very far back in the epigastric excavation, and extends towards the left side, so as to occupy the left hypochondrium to a great extent. Its pyloric third or half is in contact with the liver, the remaining or cardiac portion is in contact with the diaphragm; hence it is always the displaced organ in diaphragmatic hernia. This close connexion of the stomach and diaphragm likewise explains the peculiar sonorousness which percussion frequently elicits over the left hypochondrium and even for some distance up the anterior surface of the thorax, so that when the stomach is large and flatulent, it is often very difficult to ascertain whether the sound produced and heard in this region results from an effusion of air and liquid into the thorax, or from such a stomach filled partly with liquid and partly with air. When the stomach is full, the aspect of its superior surface is more directly upwards and less forwards than in the empty state; but a considerable portion of the anterior part of this surface, as well as of the greater curvature, is in contact with the abdominal parietes. The great curvature of the stomach for three-fifths of its extent towards the pylorus is closely connected with the upper surface of the transverse arch of the colon, and with the two anterior laminæ of the great omentum which come in contact along the line of that curvature, enclosing between them the anastomosis of the gastro-epiploic arteries. Hence we sometimes find that, in cases of perforation of the stomach, the opening is filled up by the adhesion of the wall of the colon to the serous coat of the former viscus, and the effusion of its contents is thereby prevented; and it has been said that fluids may pass through an ulcer of the great curvature and be effused between the laminæ of the omentum, so as to point externally as an abscess.* The extent of the relation of the stomach to the liver varies; in some instances it extends as far outwards as the gall-bladder; and Cruveilhier mentions a case in which gall-stones were discharged into the stomach in consequence of an adhesion formed by its anterior surface with the gall-bladder. The stomach rests by its posterior and inferior surface on the superior lamina of the transverse mesocolon, which forms a natural floor to the epigastric region, and separating it from the umbilical region. Posteriorly the same lamina of the transverse mesocolon separates it from the inferior transverse portion of the duodenum and from the head of the pancreas, which again are separated from the spine by the aorta and crura of the diaphragm. The lobulus Spigelii of the liver is seen behind, and to the left of the lesser curvature of the stomach, and when the latter is drawn downwards and the liver forwards, this lobe projects, pushing the gastro-hepatic omentum before it; the lesser curvature has likewise among its connections posteriorly the cœliac axis and solar plexus, and like the great curvature has an arterial anastomosis running along it formed by the superior pyloric and gastric arteries. The spleen is very intimately connected by the gastro-splenic omentum to the left extremity or great *cul-de-sac* of the stomach, and seems, as it were, moulded upon it, following it in its movements, and each accompanying the other in its displacements: behind this portion of the stomach are the tail of the pancreas, the left kidney, and supra-renal capsule. The point of entrance of the œsophagus into the cardiac extremity of the stomach is overlapped by the left lobe of the liver and its left lateral ligament, and it rests upon the decussating muscular bundles of the diaphragm.†

In the epigastric region we likewise find the first portion of the duodenum passing from left to right slightly upwards and backwards, terminating at the neck of the gall-bladder, with which it often contracts preternatural adhesions. Behind this superior portion of the duodenum, a little to the left of its termination, the ductus communis choledochus

* Blandin records a remarkable case of internal strangulation which took place by the introduction of a considerable portion of the small intestine through the foramen of Winslow into the cavity of the omentum, from which it escaped through a lacerated opening in the transverse mesocolon which firmly constricted a knuckle of the intestine and occasioned mortification of it.—*Anat. Topog.* p. 442.

† See cases recorded by Andral, Clin. Med. t. iv. and Graves, Dublin Hosp. Rep. vol. iv.

* Ledran, quoted by Velpeau, Anat. Chir. t. ii. p. 165.

† From the relations of the stomach to the abdominal parietes we are not surprised to read of fistulous communications being formed between that viscus and various regions of the abdominal surface.

descends to enter the middle portion of this intestine, the upper part of which is likewise found in this region. Here, too, we have the upper half of the head of the pancreas, the right gastro-epiploic and the gastro-duodenalis arteries.

In proceeding to remove the parts which lie most superficially in the epigastric region, we notice on the right side the vessels and nerves enclosed between the laminæ of the lesser omentum, viz. the hepatic artery and its terminal branches, the vena portæ, and the hepatic and cystic ducts, with the commencement of the ductus communis choledochus, and entwining its filaments chiefly around the hepatic arteries is the hepatic plexus of nerves; several lymphatic vessels of considerable size are also found here, and some lymphatic ganglions, the enlargement of which latter, whether acute or chronic, may retard the passage of the bile and give rise to jaundice. All these parts are invested and connected to each other by the dense cellular membrane called the *capsule of Glisson*. Behind the liver, and closely lodged in a groove, and sometimes a canal in its posterior thick margin, is the vena cava ascendens, which is still more intimately connected with the liver through the branches of the vena cava hepatica, which open into that portion of the ascending vein which is lodged in the groove. To the right of the vein are the supra-renal capsule and the upper part of the kidney, and to its left, and closely connected with the supra-renal capsule, is the semilunar ganglion. Here, likewise, are the renal or emulgent vessels and the renal plexus of nerves.

In the centre of the epigastric region, on removing the stomach, we open into the lesser cavity of the peritoneum, of which the stomach forms, in part, the anterior and superior boundary. This cavity is bounded inferiorly and posteriorly by the descending layer of the transverse meso-colon, which covers the upper part of the pancreas; above this latter gland is the cœliac axis, surrounded by the solar plexus of nerves, giving off its terminal branches, of which the hepatic passes towards the right side, and forwards to the transverse fissure of the liver, while the splenic directs itself tortuously towards the left side, along the upper margin of the pancreas. The pancreas itself is to be counted among the parts contained in this region; here it is covered by the superior layer of the transverse mesocolon, which alone separates it from the posterior surface of the stomach; hence this gland has sometimes, by contracting an adhesion with the stomach, served to fill up a perforation by an ulcer. Behind the pancreas are the vena portæ and the conflux of the splenic and superior mesenteric veins, the superior mesenteric artery, and the nervous plexus of the same name; by all of which the gland is separated from the aorta, which, again, with the pillars of the diaphragm and some lymphatic glands, separates the pancreas from the spine. To the right of the aorta, and intervening between it and the right crus, are the thoracic duct and the vena azygos, and external to each crus of the diaphragm the great splanchnic nerve is seen to connect itself with the semilunar ganglion.

On the left side the gastro-splenic omentum contains the vasa brevia and splenic arteries, the splenic plexus of nerves, and the commencement of the left gastro-epiploic artery; the great cul-de-sac of the stomach, and the spleen cover here the left supra-renal capsule, the semilunar ganglion and great splanchnic nerve, the upper part of the left kidney, and the renal vessels and nerves.

From the vast number and importance of the parts contained in the epigastric region, it cannot be a matter of surprise that it is frequently the seat of disease, and that the most serious consequences will often ensue upon strong pressure or violence inflicted upon it. It is universally known that syncope may be induced or even sudden death occasioned by a blow upon the epigastrium, even in a healthy individual; and it seems to be the favourite opinion that such results arise from the influence exerted upon the immense nervous plexus which is found here. Sometimes, however, one or more of the viscera have experienced injury, and cases of rupture of the spleen, liver, gall-bladder, or duodenum from violence inflicted on this region are not uncommon.* Every practitioner is familiar with the existence of *epigastric pulsations*, which, as they arise from a variety of causes, form a subject of great interest. Dr. Copland thus enumerates these causes, and, indeed, most of them may be deduced *à priori* from a knowledge of the anatomy of the region: *a*, nervous susceptibility; *b*, inflammation of the aorta; *c*, aneurism of the aorta; *d*, adhesion of the pericardium to the heart; *e*, tumours at the root of the mesentery; *f*, tumours of the stomach or scirrhus of the pylorus; *g*, enlargement of the pancreas; *h*, hypertrophy of the heart, particularly of its right side; *i*, enlargement of the inferior vena cava; *k*, hepatisation of the lower portion of the lungs; *l*, enlargement of, or abscess in, the liver.†

Umbilical region.—This region is distinctly and naturally separated from the epigastrium by the transverse arch of the colon and the transverse mesocolon. It is almost entirely occupied in the centre by the small intestines, and on each side by the colon, either ascending or descending. Deep seated and at the upper part of the region, we notice the inferior portion of the duodenum, which is covered by the inferior lamina of the transverse mesocolon, and terminates on the left side of the spine, just where the mesentery commences. The superior mesenteric artery crosses above and in front of the duodenum, a few lines to the right of its termination, and when the body is laid on the back the intestine seems to suffer a constriction from the artery. Such a constriction can hardly

* See an interesting paper by Dr. Hart, in the Dub. Hosp. Reports, vol. v.

† Dict. Pract. Med. art. *Epigastrium*.

exist during life, when the viscera of the abdomen are under the influence of the action of its walls, for then the direction of the superior mesenteric artery is so little downwards and so much forwards that it cannot be said to exert any pressure upon the intestine; yet it is remarkable that in many cases of ruptured intestine, the seat of the rupture has been a very short way below the continuation of the duodenum into the jejunum. The inferior portion of the duodenum rests upon the vena cava and the aorta, and is in contact with these vessels by its posterior wall. The inferior margin of this intestine descends to very near the bifurcation of the aorta, leaving no more than from one-half to three-fourths of an inch interval. We notice, moreover, in this region the obliquity of the mesentery, the arterial and venous, nervous and lacteal ramifications existing between its laminæ and the mesenteric glands or ganglions connected with the lacteals, which ganglions are often very few and much atrophied in old subjects. The convolutions of the small intestine are covered in front by the omentum, and are very closely in apposition with each other: hence they become 'matted together' by the lymph effused in peritonitis, and hence, too, in perforations, effusion of the intestinal contents by no means necessarily takes place. The looseness of the intestinal convolutions and of the mesentery by which those convolutions are tied to the spine, admits not only of their being liable to frequent introsusception, but also of being strangulated by the twisting of a knuckle of intestine. For the same reason it is that we find this intestine forming most of the herniæ which protrude from the various regions of the abdomen. The small intestine occupies the whole central umbilical region, extending likewise on either side into the lumbar regions and downwards into the pelvis. Thus it forms a considerable mass interposed between the anterior and posterior abdominal walls, and it is easy to conceive how, during an irregularly distended state of the intestine, violence applied to the abdomen in front can cause a rupture of a part of it without occasioning any solution of continuity in the wall of the abdomen.

The laminæ of the mesentery pass backwards and outwards along the sides of the spine, and entering the lumbar regions become continuous with the right and left mesocolons. By their divergence in front of the spine they form a triangular enclosure, the basis of which is formed by the bodies of the vertebræ. In this space we find the aorta, and lower down the primitive iliac arteries, the commencement of the thoracic duct, the receptaculum chyli, and several tributary lymphatics and lacteals with their ganglions, the vena cava ascendens, and the left renal vein, the lumbar arteries and veins, and many nervous ramifications from the sympathetic, and more on the sides the lumbar ganglia of the same nerve; here also we notice the fibrous insertions of the crura of the diaphragm, and the anterior common ligament of the vertebræ. Each lamina of the mesentery, as it passes outwards, crosses over the ureter lying on the psoas muscle, and the spermatic artery with the accompanying veins, and some of the musculo-cutaneous branches of the lumbar plexus, and having entered the lumbar region, covers the right and left colons, forming, at its reflections on and off the intestine, the mesocolons. Each of these portions of the colon lies very nearly connected to the posterior wall of each lumbar region, having only the lower portion of the kidney, with its surrounding adeps, interposed above. In some instances a mesocolon does not exist, and the colon is bound down to the posterior wall of the lumbar region, so that the posterior surface of the intestine uncovered by peritoneum is in direct contact with the quadratus lumborum muscle or the kidney, having only cellular membrane or fat intervening, and this occurs much more frequently at the left than at the right side: hence the not uncommon occurrence of lumbar abscess, or renal abscess, or calculi being discharged into the colon, and so finding their way out by stool. The proximity too of the portions of the colon to the ureters serves, as Velpeau has remarked, to explain how pins, or beans, or pieces of lead find their way into the bladder and become the nuclei of calculi there, or being impeded in their progress through the ureter, the calculous matter concretes around them in that canal. In confirmation of this explanation, he relates a case which occurred at La Pitié. A pin, the head of which was still found in the colon, in which it had excited considerable ulceration, had passed also into the ureter, so that a calculus, of which the pin formed the axis, projected partly within and existed partly without the canal of the ureter.* Whether the mesocolons exist or not, the right and left colons are in general so fixed *in situ*, that they rarely form the contents of a hernial sac.

Hypogastric region.—The central portion of this region is occupied by the continued convolutions of the small intestine. The right iliac region is in general entirely or almost entirely occupied by the cœcum, which sometimes has a mesocœcum and sometimes not. In the latter case, a little reticular cellular membrane, and the fascia iliaca, are all that separate the intestine from the surface of the iliacus internus muscle. Beneath the fascia the ilio-scrotal and the inguino-cutaneous nerves are seen passing outwards to their destination. The internal iliac artery and vein lie along the inner margin of the psoas muscle, covered by a thin fibrous expansion, which is a process from the iliac fascia, and deeply seated between the psoas and iliacus internus muscles is the anterior crural nerve. The external iliac arteries are crossed at their origin by the ureters, and along their course a few glands may be found either at the sides or in front. This region is one of great interest to the pathologist, in consequence of the frequent occurrence of disease

* Velpeau, Anat. Chir. t. ii. p. 175.

in it, whether originating in the wall or in the cœcum.

There is no part of the intestinal canal in which accumulations are more likely to take place than in the cœcum; and it is now pretty well ascertained by the researches of various observers that inflammation is often propagated from the cœcum distended with hardened fæces to the cellular tissue and muscles of the iliac fossa, thus exciting abscess, which may open either externally through the abdominal parietes or internally into the cœcum.* By careful manual examination of the anterior abdominal wall corresponding to this fossa, we are in general able to detect even a slight distension of the cœcum, and percussion employed here will often afford considerable assistance in forming a diagnosis. The vermiform appendix of the cœcum frequently hangs down into the pelvic cavity connected to the cœcum by a fold of serous membrane; at other times it lies in the iliac fossa, being folded up under cover of a projecting portion of the cœcum, sometimes as a natural result, and at others as an effect of morbid adhesions.

The left iliac fossa contains the sigmoid flexure of the colon, which from its cylindrical form, as well as from the circumstance of its being in general much contracted, does not occupy that region to the same extent as the right side is filled by the cœcum. The sigmoid flexure is here connected by a mesocolon similar to that of the descending colon, and its relations to the other parts contained in the iliac fossa are pretty much the same as those of the cœcum on the right side. In the centre of the hypogastric region we observe that the posterior wall is formed by the last lumbar vertebra and the promontory of the sacrum, and this region is open below, whereby it communicates with the pelvis through the superior outlet. Hence along the posterior wall we find the rectum with its mesorectum, the middle sacral artery, and the hypogastric plexus of nerves; and some of the pelvic viscera under particular conditions pass forwards into this region, and even admit of being examined during life through the anterior wall. Thus the bladder under distension comes forward, and, as the distension increases, ascends, so as often to occupy the whole of this region to the exclusion of its natural contents; so also the uterus. The vas deferens in the male and the round ligaments of the uterus in the female, and in both the obliterated umbilical arteries, the urachus and the spermatic vessels, are also among the parts belonging to the hypogastric region.

The preceding account of the abdominal cavity as it is found upon dissection, has reference chiefly to the adult male subject; but there are certain differences in the relations and positions of parts, dependent on sex and age, to which it is highly important to pay due attention. In the adult female, the chief difference arises out of the great size of the pelvis and the consequent increase in the magnitude of the lower part of the abdomen, the transverse measurement of which will be found to exceed that of the epigastric region, more especially where that region has been artificially compressed and consequently diminished in its capacity, by the custom of wearing tight stays. During pregnancy, which, as being a natural change, may be not inappropriately noticed here, the female abdomen experiences a very considerable alteration in its form, capacity, direction, the relations of its organs, and the order of its circulation.

"In the first month," says Blandin, "it seems to contract, and its walls to fall in upon themselves; but afterwards opposite changes take place. By reason of the resistance offered by the pelvis, when the uterus begins to increase, and especially when it has acquired a certain size, it makes, as it were, a protrusion upwards, and is carried into the *supra-pelvic* part of the abdominal cavity, which it dilates, especially in front, in consequence of which the obliquity of the axis of that cavity forwards is diminished. The dilated uterus is placed entirely in front, behind the anterior abdominal wall, and presses the small intestine and omentum towards the spine: the omentum, however, is sometimes, though rarely, found in front of the uterus. The diaphragm is also pushed upwards and raised as high as the level of the sixth dorsal vertebra: all the peritoneal folds of the uterus are obliterated; the peritoneum no longer descends into the pelvic excavation, the bladder and the rectum are strongly compressed, and are in some degree impeded in performing their functions; the uterus itself is inclined to one side, in consequence of the projection of the vertebral column, and generally to the right side, which, according to Chaussier, is attributable to the greater shortness of the round ligament of the right side. Notwithstanding all this enlargement of the abdominal cavity, the viscera are compressed more strongly than usual, and can become protruded with greater facility, when the distended and attenuated walls have lost much of their power of resistance. The normal irritation of which the uterus is the seat, causes a greater afflux of blood into the whole inferior part of the vascular system, and into its own vessels in particular."*

During the development and growth of the walls of the abdominal cavity some interesting changes are observed to take place in its shape capacity, and in the positions of the contained viscera. The most remarkable characteristic of the abdomen at the earliest period is its very great capacity when compared with the other cavities; this arises from the great development of its contained organs. This great size, however is manifest entirely in the umbilical region, for neither the epigastric nor the hypogastric can be said to exceed their proportional magnitude in the adult. On the contrary, both these

* See Dance in Rep. Gén. d'Anat. et de Phys. t. iv. p. 74; Meniere, Arch. Gén. de Méd. t. xvii.; and Ferrall, Ed. Med. and Surg. Journal. No. 108.

* Blandin, Anat. Topog. p. 431.

regions are proportionally much smaller than in the adult; the epigastric, in consequence of the contracted diameters of the thorax, but more particularly in consequence of the small size of the vault which is formed by the diaphragm; and the hypogastric by reason of the imperfectly developed state of the pelvis. Hence, then, we find that most of the viscera extend more or less into the middle or umbilical region, which thus exhibits a very great enlargement. The liver is the viscus which exhibits the most remarkable degree of enlargement; its two lateral lobes present but little difference in size, it extends laterally so as to occupy nearly the whole epigastrium, leaving but a small space at the left side for the stomach and spleen; it passes considerably beyond the inferior margin of the ribs, so that a great portion of it is found in the umbilical region, extending even to the hypogastrium. This great extent of space occupied by the liver necessarily causes corresponding alterations in the positions of the neighbouring viscera, and of none more than the stomach. The direction of this organ is nearly perpendicular, its pyloric extremity is found a little to the right in the umbilical region, while the aspect of its splenic end is upwards and to the left; its great curvature looks to the left side and downwards, and its lesser curvature to the right and upwards. The spleen is not altogether contained in the left hypochondrium, but also extends into the left lumbar region, and may be felt below the false ribs. The duodenum does not change its positive situation with reference to the spine, but, in consequence of the position of the stomach, its curves are more marked, the superior portion passes more decidedly upwards, and the whole duodenum is to a greater extent covered by the stomach. The rest of the small intestine is crowded backwards against the spine, and in consequence of the non-development of the pelvis is found entirely in the umbilical region; nor is it covered by the omentum, which as yet has attained but a very small size. At this early period, moreover, the bladder is an abdominal viscus; in general, very capacious and of a cylindrical form, it extends out of the pelvis to within a very short distance of the umbilicus, to which it is connected by the urachus, so that it occupies a considerable portion of the hypogastric and a small part of the umbilical regions; consequently, as Portal remarks, the shortest route by which the bladder can be reached at this early age is according to the method of the suprapubic operation, and it is only a small portion of the neck of the bladder which is at all in relation with the perinæum. A considerable portion of the rectum, also, is found in the hypogastrium, and in the female the uterus and ovaries and the Fallopian tubes. Prior to the seventh or eighth month of intra-uterine life, when the testicles enter the scrotum, they are found successively as they descend in different regions of the abdominal cavity, at first in the lumbar regions immediately beneath the kidneys, and then at different heights along the inner side of the iliac fossæ; we also observe here that process of peritoneum connected with the testicle, and extending from it to the inguinal canal, which is known by the name of the *diverticulum* of Nuck: a similar process exists in a much less developed condition in the female connected with the round ligament. The principal difference observable, as regards the large intestine in the fœtus at its full period, consists in the great curvature of that portion of it that is found in the left iliac region, occasioned by the narrowness of the pelvis admitting but a small part of the rectum.* In the progressive development which takes place during intra-uterine life, the position of this as well as of the other portions of the intestinal canal presents differences which it does not belong to the present article to examine. (See Intestinal Canal.)

The capacity of the abdominal cavity and the position of some of its contained organs, as they thus exist in the fœtus at its full period, continue pretty nearly the same for some time after birth. The enlargement, however, of the vault of the diaphragm increases the capacity of the epigastrium, while the gradual diminution of the liver affords room for the passage of more organs from the umbilical region upwards, and the stomach is allowed to take a more horizontal direction. These changes, which are gradual in the periods of life prior to puberty, become most manifest when the arrival of that period gives rise to the enlargement of the pelvis; then the umbilical region is as it were relieved from its overloaded state; the belly is less prominent, for the bladder now occupies its proper place in the pelvic cavity; the rectum, too, sinks into it, and many of the convolutions of the small intestine are found in it: thus, by the enlargement of the hypochondria in the first instance, and subsequently by the development of the pelvis, the three subdivisions of the abdominal cavity assume those proportions in their respective magnitudes which are characteristic of the adult period.

In considering the probable amount of injury inflicted by wounds which may have penetrated the abdominal cavity, we must take into account the changes which the different attitudes of the body occasion in the positions of the viscera. These changes cannot be extensive, and only regard the position of each viscus with reference to the whole cavity, the relations of that viscus to the neighbouring ones being unaltered, or nearly so. They take place in obedience to the law of gravitation, and it is so easy, by a little reflection, to deduce what the changes must be, keeping in mind the various means made use of to limit and prevent displacement, that it seems unnecessary to do more here than allude to the fact that the viscera are altered in position under the influence of such a cause.

Abnormal conditions of the abdominal cavity.—All the abnormal conditions of

* See on this subject Portal, Anat. Méd. tom. v. Blandin, Anat. Topog. and Meckel, Anat. Gén. Desc. et Path. tom. iii.

the abdomen may be considered under two heads: 1. as they regard the parietes of the cavity; and, 2. as they refer to the positions of the contained organs. We shall first examine the abnormal conditions of the parietes.

Congenital malformations of the abdominal parietes.—The first class of these malformations which demands consideration is that which depends on a defect in the development of the structures which form the abdominal walls, and these are by far the most numerous. In examining them it is to be borne in mind that many of the abdominal viscera exist before the walls of the cavity, which are formed around the viscera, and that the anterior wall is later in its formation than any of the others. The cavity containing the viscera seems at first to be a continuation of that of the umbilical cord, its walls being continued from the sheath of the cord. A distinct separation does not appear to take place until the skin has become developed, when a line of demarcation is evident between the skin of the abdomen and the sheath of the cord.

The anterior wall may be deficient on both sides to a greater or less extent, the lateral and posterior being also more or less involved. The maximum is when the defect extends not only throughout the whole anterior abdominal wall, but also to that of the thorax, leaving all the viscera of both abdomen and thorax visible, being covered only by a thin membrane; and frequently congenital deficiencies of the lower part of the anterior wall of the thorax are accompanied by a more or less extensive defect of the upper part of the same wall of the abdomen, and the heart is included with the abdominal viscera, which are rendered visible, and which, in some instances, protrude forwards. There may, however, be a congenital deficiency of, or fissure in the deeper seated elements of the anterior abdominal and thoracic wall, and yet the skin remain perfect and cover the protruded viscera.* But the thoracic parietes may be perfect, and yet there may exist an imperfect condition of the abdominal parietes to a greater or less extent, which imperfection evidently results from the continuance of a greater or less portion of the abdominal wall in that condition in which it naturally exists in the early stages of fœtal development. In such cases the viscera are covered by an expansion which is continuous with the sheath of the umbilical cord. When the deficiency of the abdominal wall exists to a great extent, the tumour formed by the protruding viscera is designated by the term *eventration;* but if the defect be very limited, and exist, as it generally does, at the base of the umbilical cord, then the protrusion is an *exomphalos* or *congenital umbilical hernia*. Both, as Isidore Geoffroy St. Hilaire remarks, are results of an arrest in the development of the abdominal walls, with this difference, that in the former the cessation of development takes place at an early period of fœtal existence, but in the latter at a late period. In conformity with the same laws, under the influence of which the arrest of development took place, we find that, as in the progress of the natural formation, the small intestine is the last to enter the abdominal cavity, so a larger or smaller portion of that intestine is generally found in the tumour of a congenital exomphalos. The nature of the contents of an eventration depends evidently on the extent of the deficiency and the region of the abdomen which is most involved.

In some instances the peritoneum is deficient to an extent corresponding to that of the deficiency of the abdominal parietes. This is a rare occurrence, and is generally met with where the defect of development is very extensive.* There are cases, however, where, although the defect was small, the peritoneum was absent to a corresponding extent, and the intestines protruded through the opening in a naked state.†

The congenital inguinal hernia must likewise be referred to an arrest in the development of a very small portion of the anterior abdominal wall. The canal of communication which at one period exists between the peritoneal sac and the sac of the tunica vaginalis remains pervious, the natural process by which it is closed having been arrested. This mode of explaining the formation of congenital bubonocele does not preclude the possibility of its accidental occurrence, the material which closes the canal having given way under the influence of some force applied to it.

The superior wall of the abdomen sometimes presents a defect of development, giving rise to the congenital perforation of the diaphragm, through which herniæ take place into the thorax. Such a perforation may exist on either side, although it is much more frequently found upon the left. (See Diaphragm.)

The malformation commonly known under the name of 'extroversion of the bladder,' has also connected with it an imperfect state of the anterior abdominal wall inferiorly, in consequence of the separation of the ossa pubis and of the recti abdominis muscles, and I believe, in general, the absence of the pyramidales. (See Bladder, Abnormal Anatomy.) In these cases the umbilicus is generally situated much lower than usual, and some writers have fallen into the absurd error of supposing that it was absent altogether, in consequence

* See Geoffroy St. Hilaire's description and plate of an hyperencephalous fœtus: Monstruosités Humaines, pp. 183 & seqq. plate 15.

* See a case by Ruysch, (observat. lxxii.) in which the stomach, intestines, and spleen were situated externally to the cavity of the abdomen. Also one by Robinson, in which the defect extended from the abdomen to the umbilicus. Amer. Journal of Med. Sc. Feb. 1833, p. 346; and a very interesting and well-narrated one by my learned friend Dr. Montgomery, in the Trans. Coll. Phys. Dub. vol. i. New Series. See also several other cases referred to in Meckel, Handbuch Der Pathol. Anatomie, Band. i. p. 97—139.

† See Fried, de fœtu intestinis plane nudis extra abdomen propendentibus nato, in Sandifort Thesaur. dissert. t. i. Also Howell, in London Med. and Phys. Journal, vol. xlv. 1821.

of its having escaped their notice by being covered and concealed by the protruded bladder.

A second class of congenital malformations of the abdominal parietes arises from an excess in the development of certain parts, as a numerical increase in the muscles, vessels, or nerves entering into the formation of the abdominal parietes, or from the development of a part of a second fœtus in connexion with the abdomen. Of the former it is extremely rare to meet with instances among the muscles or vessels of the abdomen; occasionally we do find an unimportant increase in the number of the costal attachments of one or more of the muscles. As to the latter several cases are recorded in which fœtuses exhibited an arm or leg, or even a portion of the trunk of another implanted upou the abdominal wall, or, as is a very rare occurrence, included in it; constituting a subdivision of that form of monstrosity which has been called *Diplogenesis*. We refer to the article MONSTROSITY for details on this subject.

Morbid conditions of the abdominal parietes.—These are such as are common to all parts compounded of the same elements as enter into the formation of the abdominal walls, which it would be superfluous to particularise here.

Congenital malformations of the abdominal cavity.—In many acephalous fœtuses the abdominal cavity is more or less curtailed of its due proportions, the deficiency existing at its superior part. Where the inferior part of the thorax or the pelvis is malformed, the abdominal cavity will also be necessarily more or less affected.

Under this head we may refer to the anomalies which arise from the congenital malposition of the viscera, which may extend to the whole contents of the abdomen, or may affect only one or more viscera. Such are the cases of complete transposition of the viscera, where those which in the normal state are on the right side are found upon the left, and *vice versâ;* thus the liver is found on the left, the pylorus on the left, the cardiac extremity of the stomach and the spleen on the right, &c. &c. The aorta and vena cava too change places, and the openings in the diaphragm alter their positions along with the parts which respectively pass through them. The same transposition generally extends also to the thoracic viscera. In many of the instances in which this transposition has been observed, the individuals have lived to the adult period of life without exhibiting any symptom indicative of the unusual position of the internal organs.*

Single viscera are likewise often found transposed or in unusual positions, occasioning necessarily corresponding changes in the parts which are connected with them. It is unnecessary to allude further to them here, as they will be treated of in the articles appropriated to those viscera.

* See Metzger de Translocatione Viscerum, 1779; also instances in Haller, Op. Minora, t. iii.; and several cases of modern date, of which one of the most complete is that published by Bryan in the Transactions of the Irish College of Physicians, vol. iv.

The morbid conditions of the abdominal cavity are the results of disease affecting its lining membrane or its contained viscera and other parts intimately connected with it. See PERITONEUM and INTESTINAL CANAL.

For the Bibliography see that of ABDOMEN and INTESTINAL CANAL.

(R. B. Todd.)

CELLULAR TISSUE.—*Tela cellulosa, textus mucosus, corpus, cribrosum,* cellular membrane, reticular membrane, filamentous, areolar, laminar tissue, &c. (Fr. *tissu celluleux;* Germ. *Zellgeweben.*) The cellular tissue is the most universally diffused element of organization, and constitutes the basis of every animal body. It consists of a soft, areolated, and elastic substance. A somewhat similar structure also exists in vegetables, constituting their most simple or elementary texture.

In systematic works the cellular tissue is generally considered as a solid substance; but as it really exists in the animal body, it is a compound of solid and fluid materials; for in no part of any animal is the cellular membrane ever entirely devoid of fluid. This union of fluid and solid parts is indeed indispensable to organization, since there is no animal, or even vegetable, in which it may not be demonstrated. In the zoophyte the entire body appears to consist of the cellular tissue, and even in man it enters so largely into the formation of the different organs, pervading equally the most delicate and the most solid parts, that it constitutes a species of mould of the whole body and of its individual parts; indeed, if we except the enamel of the teeth, and, as some authorities contend, also the nails, the hairs, and the epidermis, there is no solid in which it may not be detected.

Many anatomists have included the adipose tissue under the general denomination of cellular membrane, but as the vesicles of the former are distinct from the cells of the latter, both as regards their formation and the nature of their contents, we rather incline to adopt the views of Malpighi, W. Hunter, Béclard, and others, who contend that the adipose and cellular tissues are distinct and separate structures. (See ADIPOSE TISSUE.)

Arrangement.—The most striking and important fact relative to the cellular tissue is its uninterrupted continuity throughout the whole body, there being no part or region, however insulated it may appear to be, in which this communication may not be demonstrated. Whilst we fully admit this general communication, it is yet necessary to state that the cellular tissue may be appropriately divided into two parts: the first division, called from its disposition the common or interstitial portion *(textus cellularis intermedius vel laxus)*, is that which occupies the spaces left between the various organs in all parts of the body; the second division is distinguished by the name of the special cellular membrane *(t. cellularis* *strictus, t. cellularis stipatus)*, because it is proper to the several constituent parts of the body, investing each of them, and penetrating into their internal structure.

Of the common cellular membrane.—It is in this division that the connection to which we have just referred is most free. Thus in the subcutaneous tissue placed between the skin and the fasciæ of the muscles, there is an universal and evident communication. Again, in the head, the cellular membrane of the external parts communicates with that of the internal through all the natural apertures—through the foramina of the base and other regions of the skull. From the face and cranium the connexion may readily be traced to the neck, whence, after having pervaded all its parts, it passes in one direction behind the sternum and upper ribs to the thoracic cavity; and in another underneath the clavicle and scapula on either side, to the arm-pit, which may be regarded as the common point of junction between the cellular substance of the neck, the trunk, and upper extremity.

The cellular tissue of the thorax is continuous with that of the abdomen through the openings of the diaphragm, and particularly beneath the sternum, around the aorta, the inferior vena cava, and the œsophagus. In a similar manner the connexion may be followed from the abdomen to the pelvis; from the former of these cavities under the crural arch to the inguinal region, which constitutes the point of union between the trunk and the lower extremity; whilst from the pelvis the communication extends in one direction by the side of the rectum and urethra to the perineum, scrotum, and penis; and in another by the obturator foramen and the ischiatic notch to the thigh.

In addition to these, which are the principal connexions, the common cellular membrane is united in every direction with the special division; the details, however, of these communications belong to the descriptive anatomy of the several regions, to the articles on which the reader is referred.

The quantity of the interstitial tissue varies according to the age and temperament of the individual, and to the region of the body in which it is examined; but, independently of any original differences which exist, it is well known that the mode of living and habits of the individual have a great influence in this respect: thus an habitual full diet, especially if conjoined with indolence, causes a great accumulation of the cellular substance; whilst, on the contrary, a spare or moderate diet and exercise will reduce it in a remarkable degree. These differences depend, probably, more on the accumulation of serous fluid and on the repletion of the bloodvessels, than on the actual increase of the proper filamentous tissue: we can in this manner, and in no other, understand how, by by what in England is called *training*, the bulk of the body may be so rapidly diminished.

The proportion of this tissue varies also in the different regions of the body; but as it is in an especial manner subservient to the production of free motion, it is principally accumulated in those parts which are most moveable. It is on this account that it abounds on the face, especially around the globe of the eye and about the cheeks, and also on the forepart of the neck and of the trunk in general. In the limbs it is met with in considerable quantity in the flexures of the joints, in the axilla, the elbow, the wrist, and in the palm of the hand; also in the groin, in the ham, in the front of the ankle, and in the sole of the foot. The superficial muscles, which are very moveable, are separated from each other by thicker layers of membrane than the deeper-seated and more fixed. It may also be remarked that those important organs, which are most liable by their structure or connexions to rupture or other effects of external violence, are carefully protected by being lodged in a large quantity of cellular substance. It is thus that we find the pancreas and the kidneys enveloped in this tissue in the abdomen; the bladder and genital organs in the pelvis; and the bloodvessels and nerves in all parts of the body.

Of the special cellular membrane.—Each organ in the body is invested in a proper covering of the cellular tissue, and also receives into its interior, processes which envelope and join together its component parts.

The investing cellular membrane *(t. cellularis strictus)* is united by one of its surfaces, the external, with the general cellular tissue, and by the other or internal with that entering into the organ. It presents many peculiarities as to the mode of its connexion; the solid parts, for instance, as the glands, muscles, and nerves, are entirely surrounded by cellular envelopes; and a somewhat similar disposition is observed around the bloodvessels, lymphatics, and excretory tubes. On the contrary, the skin, the mucous and serous membranes, having one surface free or unattached, are only connected on one side with the cellular tissue, which is distinguished according to its situation, by the terms subcutaneous, submucous, and subserous cellular tissue. The covering thus afforded to each individual organ serves in a certain degree to insulate and separate it from the surrounding structures, and in this manner it often tends to limit the progress of disease; but as we have just seen that this covering is united both to the interstitial and to the penetrating cellular tissue, it would be equally contrary to reason and experience to expect that it should constitute, as some authorities have contended that it does, a species of atmosphere around the various organs, confining their natural actions and morbid phenomena.

The penetrating cellular tissue *(t. cellularis stipatus)* constitutes so essential a part of organized structures, that there is no organ in which it may not be detected. It exists in the substance of bone, cartilage, and ligament, although it is distinguished in these structures with difficulty, in consequence of their great density; it penetrates between the most minute fibres of the muscles and nerves; between the coats of the bloodvessels and lymphatics; also between the layers composing the skin and mucous membranes; and lastly, it enters into the substance of the absorbent and secreting glands, investing their several component parts.

Structure and organization.—If a portion of cellular tissue void of adipose substance be examined with the naked eye, and for this purpose that which intervenes between very recent muscular fibres may be advantageously selected, it will be seen that it is composed of an immense number of delicate and semi-transparent filaments, having very much the appearance of the finest threads of a spider's web. These fibrils cross each other in various directions, and in this manner intercept innumerable spaces, which communicate one with another, and exhibit a vast variety of figures. The small spaces or areolæ which are thus produced constitute what are called the *cells* of this tissue; but as there is nothing determinate either in their size or shape, which evidently vary according to the degree of traction exercised in separating the filaments; as they communicate together, and consequently are not circumscribed; as they are in fact simply the interstices left between the fibres, the expression in common use is calculated to convey an erroneous idea of the real nature of these spaces.

If the investigation be prosecuted with the aid of a powerful microscope, a very beautiful appearance will be presented, of which it is impossible to convey an adequate idea by any description. We shall still observe fibres crossing in all directions; but although I have had many favourable opportunities of making these observations, I have never been able to detect in the cellular fibre that *linear arrangement of globules* described by Dr. Milne Edwards, and which has of late years been very generally supposed to pervade all the elementary fibres of the body. A number of globular particles may, it is true, be seen at irregular distances, either clustered together or dispersed in an isolated manner, but they do not enter into the formation of the fibre. The results, then, of careful inspection disprove the ideas of former anatomists, some of whom, Ruysch and Mascagni for example, supposed that the cellular fibre was entirely vascular, whilst others imagined it to be an expansion of the nerves: it is now generally admitted that the basis of the cellular substance is a solid and elementary fibre; and although to the naked eye it often presents a membranous form, yet microscopical observation evinces that the plates of membrane are distinctly composed of solid fibres. The interstices or cells always contain in health a very thin albuminous fluid, which has a great resemblance to the secretion of the serous membranes, and also to the serum of the blood; and hence it is often termed the *cellular serosity.* This fluid, which must be regarded as an integrant part of this tissue, has a great influence on its properties, so that if it be entirely removed, as by desiccation, the membrane becomes hard and brittle, and its elasticity is almost lost; or if it be accumulated in excess, as we often see it in disease, the elastic force is also destroyed.

Bloodvessels and lymphatics.—An inquiry into the relations which exist between the cellular and vascular tissues, would lead to the important question, how far vascularity is essential to organization? Without entering into this investigation, it may be remarked that the cellular substance is provided with bloodvessels; and although the greater number of these merely traverse the membrane in order to reach other parts, yet the phenomena of nutrition and absorption shew that a vascular apparatus must exist in connexion with the cellular tissue.

Nerves.—It is impossible to trace any nervous filaments to the cellular fibres, although such threads may be seen passing between them to the neighbouring organs. The insensibility in its healthy state also seems to indicate the absence of nerves; but as pain is experienced during inflammation, we must admit the existence of some communication with the sensorium.

Chemical composition.—The cellular substance contains, like all the soft solids of the body, a large quantity of water: when this is evaporated, the fibres and cells adhere to each other, and present a membranous appearance. Analysis shews that albumen and gelatine compose this substance; the former predominating, and being in a state of coagulation, bestows on it the necessary degree of firmness and resistance.

Properties.—As we shall have occasion in a future article (see MEMBRANE) to consider this subject more minutely, it will suffice if we here remark that the most important property of the cellular substance is a species of contraction which produces in all the soft parts a constant state of tension or tone, which is one of the most remarkable qualities of living bodies. The cause of this peculiar condition, in whatever part it is evinced,—in the skin, in the cellular tissue, in the muscles, in the vessels, &c.—is the result of a property inherent in membranous matter, which some authorities refer to muscular contractility, and others to elasticity; whilst many eminent physiologists, denying both these hypotheses, conceive that the contraction to which we are alluding is of a character *sui generis,* and which they have called *tonicity, vis cellulosa, tonic contraction, contractility of tissue,* &c. I confess that none of these theories have ever been to me satisfactory; because, as regards the first, there is no resemblance between the phenomena connected with the contraction of membranous parts, and those of muscular contraction; whilst, as respects the second, the resiliency by which the skin recovers itself after pressure has been made on the external surface, and the retraction and separation of the sides of an incision inflicted on the integument, being observed only during life, and never after death, prove that the results of cellular contraction are, in some important respects, different from those of common elasticity. Those writers who, in consequence of the difficulty of referring the phenomena under consideration to either of the known causes of contraction, viz., muscular contractility and elasticity, have imagined the existence of a new kind of contractile power, have, without adducing any sufficient proof in corroboration of their views, had recourse to an expedient but too frequently adopted by physiologists when the real nature of any vital process escapes their detection.

The only way in which the apparently contradictory results of experiment and observation can be reconciled, is by attending to a combination of vital and physical processes, that has been too much neglected in investigating the characters of living bodies; that is to say, it must be recollected that "life," to borrow the philosophic expression of Dr. Arnott,* "is a superstructure on physics and chemistry," and that those phenomena which are essentially dependent on the ordinary laws of matter are controlled and modified by the superior principle of life. In the case of the cellular substance this remark is peculiarly applicable; and from reflecting on all the facts relative to that tissue both in a state of health and disease, I have arrived at the conclusion that the phenomena of its contractile force are the combined results of one of the common properties of matter, viz., elasticity; and of a vital process, viz., nutrition. It is a well-known fact that the existence of elasticity in any inorganic substance requires a particular state or arrangement of its particles, and that if the necessary condition be but partly fulfilled, or be entirely wanting, that property is only slightly displayed, or is totally absent. The same principle strictly applies to the living body; and in the cellular substance the required condition is, *a definite proportion between the solid fibres and the interstitial fluids*, which state is maintained by the agents of the circulation and secretion, namely, the bloodvessels and lymphatics. Any thing which interferes with this proportion, either the excess of fluids, as in anasarca or phlegmonous erysipelas, or the diminution of the humours, as in old age and in many diseases, will impair or destroy the phenomena observable in the sound state of the cellular membrane, and will explain in the former case, the *pitting* which is seen on making pressure on the skin; and in the latter, that flabbiness and wrinkling of the integument about the face and other parts of the body, so characteristic of those advanced in life or reduced by disease. We can in this manner understand how a class of phenomena may be dependent on a physical property, and yet be modified by the condition of the vital powers, so as to become impaired by disease, and destroyed by death.

The exhalation and absorption of which the cellular substance is the seat, have been supposed by many high authorities to be effected by its elastic contractility; but it is probable that these phenomena, although in part dependent on that property, are principally produced by the power of imbibition, which, according to the experiments of MM. Magendie and Fodéra, exists in all the soft parts of the body.

Functions.—The offices accomplished by this substance in the economy seem to be, first, that of uniting together the various constituent parts of the body, and of keeping them *in situ* by its contractile force; secondly, of facilitating their movements by means of its lubricating fluid, and thus preventing the injurious effects of friction and concussion; and lastly, of furnishing an appropriate structure for their reception. It has also been supposed that, being a bad conductor of caloric, it will tend to preserve the uniform temperature of the body.

Development.—The first trace of an organized substance observed in the embryo consists of a very soft and pulpy cellular tissue, which at this early period is loaded with fluid; and being homogeneous in its nature, it presents neither fibres nor interstices, although it may be readily permeated by air or liquids, so as to produce small cells, and may likewise be drawn out into glutinous filaments. In proportion as the several organs become developed, it acquires greater consistency, and is at the same time diminished in quantity. At the period of birth it is still, however, in a very soft and imperfect state, and only acquires its proper density by slow degrees; in old age, being deprived of a large portion of its fluid, and perhaps otherwise deteriorated, it loses much of its elastic force; and this circumstance, joined to its diminished bulk, is a principal cause of that loss of rotundity so conspicuous in the bodies of aged persons, and of the flabbiness of the several organs.

The power of reproduction is greater in this than in any other tissue, so that it is not only readily formed again within certain limits when it has been destroyed, but it even appears to supply the place of other and dissimilar structures which may have been lost by disease.

The cellular substance presents but few modifications of importance when examined in the different classes of animals, except, indeed, that it is generally believed to constitute the entire body in those species that are placed at the bottom of the scale. The Porifera afford an example of the simplest form of the cellular texture with which we are at present acquainted; the body of these animals consists of a soft gelatinous substance composed of translucent globules, which, however, are not perceptibly joined together; so that there is in this instance nothing of that fibrous structure, which is the great characteristic of the cellular membrane in the human body and in the higher orders of animals. In the semifluid and jelly-like body of the Polypifera and of some of the Acalephæ, there is merely a pulpy substance, which, although it may exhibit a distinct digestive cavity, and even tubes communicating with this, yet no muscular tissue has hitherto been discovered. In these animals, however, rapid movements are seen in the cilia; and the tentacula, when present, together with the entire body, are capable of spontaneous motion; it is evident, then, in these and other instances, that if, as is generally supposed, there be an absence of muscles, the cellular tissue must be endowed with a property totally wanting in that substance as it exists in the higher animals. When it is con-

* Elem. of Physics, Introd. p. xxvi.

sidered how little is known respecting the real structure of the Infusoria, Zoophytes, &c., and when the numerous discoveries which have of late years been made in these and much higher animals, of parts whose existence was formerly doubted or denied, are recollected, we shall be inclined to think that there are special organs of motion provided; for it would be in direct opposition to the simple but constant laws observed in the animal creation, were the organic tissue, entitled the cellular, to acquire in the lower classes a power of contraction, which in the higher it does not possess, and which property is the endowment of a totally distinct system of organs, namely, the muscles. Whichsoever of these opinions be correct, there is no doubt that in the least perfect animals, a soft and gelatinous matter, analogous to the cellular tissue, and loaded with fluids, greatly predominates. As we advance in the scale, it is found that organized substances of a diversified character are developed in the nidus afforded by this cellular texture, the proportion of which to the other structures becomes thus diminished.

Morbid conditions of the cellular tissue.—As the cellular membrane is so intimately united with all other organs, it is very liable to be involved in diseases commencing in these parts; but morbid action also very frequently arises primarily in this tissue. It is subject to—1, inflammation, acute and chronic, circumscribed and diffused; to the effects of inflammation, thickening and induration, suppuration, ulceration, and mortification; 2, infiltration of blood, serum, air, and occasionally of other substances, as urine; 3, induration, occurring in new-born infants; 4, morbid growths, such as fibrous productions, cysts, melanosis, scirrhus, vascular sarcoma; 5, foreign bodies; 6, preternatural increase or hypertrophy, and degeneration, or atrophy.

I. Inflammation.—This tissue is very frequently affected by inflammation, which may either present itself under the form of a distinct affection, as when it attacks the subcutaneous cellular membrane especially, or it may occur as a part of some other disease, as when inflammation of the parenchyma of the lungs, liver, &c., spreads to the cellular tissue in which this substance is universally involved.

a. Acute circumscribed inflammation, or phlegmon.—The anatomical characters of this form of inflammation of the cellular substance are essentially the same in whatever part of the body it may arise, either in the subcutaneous tissue, or in that part which penetrates into the interior of the various organs; it will, therefore, be proper to trace the effects of it in a general manner.

1. *Congestion of the bloodvessels.*—The effects of irritation on the capillary vessels, in which the phenomena of inflammation are principally observed, may be beautifully seen with the aid of a sufficiently powerful microscope in the transparent membrane of the frog's foot. After having familiarized the eye by watching the circulation for a short time, we shall find that the first effect produced by the application of an irritant is a distinct and evident acceleration of the blood's motion. I have not been able to satisfy myself of that diminution of the calibre of the vessels which is said by some observers to accompany this acceleration. If the irritation be repeated, or if its power in the first instance were considerable, it will be seen after a certain time that the capillary vessels become dilated, that the blood moves more slowly, and often that it oscillates and circulates apparently with difficulty; its constituent parts become less distinct, the particles being crowded together. If the effects of the irritation now subside, the dilated vessels contract and recover their proper calibre, the blood again moves more freely, and the circulation regains its natural state; but, on the contrary, if the morbid action still persists, the membrane begins to grow opaque, either in consequence of the engorgement of the vessels, or, as it has appeared to me, from an extravasation of one or other of the constituents of the blood; or, lastly, the circulation altogether ceases, the vessels are further enlarged, the blood is stagnant, and is evidently deteriorated in quality, and the colour becoming deeper and deeper, is at length perfectly brown, or even black. This is the order in which the phenomena in the derangement of the circulation occur; and although they have been more particularly studied in microscopical observations on the lower animals, yet many of them are daily to be observed in the human body during the progress of inflammation. Whilst the inflammatory action is confined to the first of the above stages, in which there is merely a preternatural excitement of the circulation, it may be arrested and put an end to without any further morbid change; and this may even happen in the second stage, where the blood, although accumulated and retarded in its motion, still circulates in its proper vessels. This speedy termination of the disease has been called by the French writers *delitescence*.

2. *Effusion.*—When the bloodvessels are greatly congested and dilated, it usually happens that a part of their contents escapes, and the cellular tissue becomes loaded with coagulable lymph, more or less tinged with blood according to the vascularity of the affected part, producing that condition which has been called *red induration*. This substance, by agglutinating together the fibres and layers, causes the hardness which is so perceptible on pressing the diseased part. At the same time that this solid deposition takes place in the centre, it is found that the circumference of the inflamed part is soft and œdematous, in consequence of the cells being distended with a fluid which appears to be the serum of the blood. Although the cellular tissue is rendered more firm to the touch by the effusion of lymph, yet, as happens in the other organized structures of the body when attacked by acute inflammation, the cohesion of its fibres is diminished, and it is, consequently, more easily torn than in its natural state, and its elasticity is also greatly impaired. The preceding changes may be very beautifully observed in the progress of pneumonia, when the substance of the lungs is passing into that

condition which is called *red hepatization.* I have in my possession a specimen of commencing hepatization, taken from a lung in another portion of which that change was quite complete. In this preparation a portion of the pulmonary tissue is of a reddish brown colour, and evidently infiltrated with a solid substance, consisting, it may be presumed, of fibrine mixed with the colouring matter of the blood. The manner in which this deposition took place in the cellular tissue of the organ is distinctly seen, the reddish colour being gradually shaded off till it is lost in the healthy structure.

It sometimes happens that the morbid action now ceases, and that by a process of absorption the interstitial effused matter is removed, so as slowly to restore the part to its proper condition: this is the termination of inflammation to which the term *resolution* is applied.

3. *Suppuration.*—It usually happens in acute inflammation of the cellular tissue, that after the lapse of a certain period, a softening takes place towards the centre of the circumscribed hardness, in consequence of the diminution of cohesion above described gradually increasing, and of the deposition of purulent matter. It is not certain how the pus is formed in the first instance; several modern pathologists, especially in France, imagine that the lymph and serum which were previously effused experience a change by which they are converted into pus, a theory which is rendered probable by the physical properties of pus so nearly resembling those of the blood: according to other authorities, pus is a proper secretion derived from the neighbouring arteries. I believe that in the beginning the purulent matter results from changes in the effused matters; but that when suppuration is fully established, the pus is poured out or secreted from the bloodvessels. In the commencement the pus is observed in the cells of the tissue, under the form of whitish spots; subsequently the walls of these interstices are broken down by the softening alluded to, and the purulent matter is collected together so as to constitute an *abscess*, which is surrounded by a rather dense layer of cellular tissue, still retaining the characters of inflammation. This layer constitutes the sac of the abscess, and presents at first a rough and reddish surface; but it soon happens that the walls acquire a greater firmness, and that the surface of the sac assumes very much the appearance of a mucous membrane.

4. *Ulceration.*—When an abscess has thus been formed, the cellular tissue intervening between it and the external surface of the body, is removed by the action of the absorbents. This process, which is always preceded by inflammation, and accompanied by suppuration, is distinguished from various other morbid actions of the absorbents by the term of ulceration. Other instances of ulceration occurring in the cellular tissue might be adduced; *ex. gr.* the separation of the slough in carbuncle, after extravasation of urine, &c.

5. *Mortification.*—If the inflammatory action be sufficiently intense, it causes the destruction of the vitality of the part affected, and probably in the manner suggested by Professor Andral. "In the most acute form of hyperæmia,* the circulation of the blood is suspended, and if this stagnation be prolonged so as to become complete, the parts being gorged with blood that is no longer renewed, and which, therefore, soon becomes unfitted to support nutrition and life, must necessarily perish, and in this manner gangrene is produced, as in the experiments performed by Dr. Hastings. In these cases the black colour announces the stagnation of the blood, and this stagnation being prolonged, must of necessity lead to gangrene. Such, in my opinion, is the manner in which the species of gangrene usually attributed to excess of inflammation, is produced." M. Gendrin has ascertained by dissection that some of the vessels are filled with coagulated blood; whilst others are actually ruptured, and allow their contents to escape. The cessation of the circulation has for a long time been remarked as the most striking character of mortification; in fact, that cessation, in whatever manner it may have been induced, whether by inflammation, by continued pressure, by the application of tight bandages to a limb, &c., is in the great majority of instances the immediate cause of mortification. The consequence of this loss of vital action is, that the natural properties and appearance of the cellular tissue are destroyed; the affected part becomes discoloured, usually assuming a black or ash-coloured appearance; the proper texture is lost, and the part is infiltrated with a dark sanious fluid, and is subsequently converted into a shapeless mass of pulpy substance, which is cold to the touch, and extremely offensive to the smell, owing to the gases which are generated by putrefaction: in fact, the part is dead, and presents the usual appearances caused by the decomposition of animal matter, conjoined with those which result from the previous effects produced in the circulation by the inflammatory action, especially the engorgement of the bloodvessels. These are the changes induced in the cellular substance when it is attacked by humid, or, as it has been called, inflammatory gangrene. In dry gangrene, on the contrary, the black and discoloured part shrivels up, and does not undergo the same changes which are produced by the decomposition of a texture which is loaded with fluids.

b. Chronic inflammation.—As we find that in phlegmon there is a great tendency to the formation of pus, so in chronic inflammation there is usually a deposition of solid matter, which produces more or less of induration and enlargement. This deposition seems almost in every instance to occur in the cellular tissue, either where it is interstitial, or where it penetrates into the interior of the several organs. This is observed among other parts in chronic

* This is a general term employed by M. Andral to designate the increased quantity of blood which is contained in the capillary vessels of any organ, without any reference to the cause which produces the accumulation. In the passage above quoted, he is speaking of acute hyperæmia, which is synonymous with acute inflammation.

inflammation of glands, as the testis, mamma, liver, tonsil, &c.; in the lymphatic glands, especially in scrofulous persons; in various diseases of the joints; in the hard swellings so often seen in scrofula, gout, and rheumatism; in imperfectly cured erysipelas, pellagra, and elephantiasis; in the callous edges of old ulcers; in the uterus, labia pudendi, and prepuce of the penis; and, according to Otto,* in that peculiar induration of the cellular tissue which occurs in new-born children. This distinguished pathologist, in common with many other continental writers, attributes phlegmasia dolens to the same cause. The incorrectness of this opinion has been demonstrated by the researches of Dance, Arnott, Lee, and others. (See Vein.)

The great induration often induced by long-continued chronic inflammation was called by the older writers *scirrhus;* and even in the present day most of the French pathologists apply that term to the hardness thus induced, as well as to the malignant disease, to indicate which English practitioners restrict the word.

The substances that are effused into the cellular tissue in chronic inflammation are various, according to the part attacked, the circumstances of the disease, constitution, &c. It generally consists of a whitish or greyish matter, of a lardaceous, homogeneous appearance, causing what is called by modern pathologists, *white induration;* and sometimes it is of a yellowish, or even bluish colour. It is doubtful whether this substance consists of the fibrine or albumen of the blood, or of some newly formed material. In scrofulous individuals the deposition consists of the well-known caseous matter, so characteristic of the strumous diathesis; lastly, this form of inflammation, especially in strumous constitutions, often leads to the formation of *chronic abscess*, the contents of which, as Gendrin, Mayo, and others have observed, do not, however, consist of true pus, but of serum generally mixed with a flakey matter, or even tinged with blood.

c. Spreading or diffuse inflammation.—The cellular tissue, constituting in all parts of the body an uninterrupted secreting surface, is subject to spreading inflammation, which, from the extent of the parts implicated, the disorganization induced, and the alarming character of the attendant constitutional disturbance, must be regarded as one of the most formidable diseases to which the human body is subject. In whatever manner this disease originates, whether from poisoned wounds, from phlegmonous erysipelas, from external injury, or from any other cause, it progressively and rapidly attacks a large extent of the cellular tissue, often invading an entire limb, or even a considerable part of the trunk. In examining parts thus affected after death, they are found to be variously altered, according to the duration of the disease and the order in which they became involved; in those which are most recently implicated, the cellular substance is merely œdematous, containing a large quantity of limpid or reddish-coloured serum, which readily flows out on making an incision, and which afterwards acquires more consistence, and becomes more deeply coloured. In the subsequent stages, pus, sometimes pure, sometimes discoloured, is effused: the matter is at first contained in the cells, which are gorged with a whitish semifluid matter, but afterwards *depôts* of matter take place in the disorganized tissue; there being, however, no proper cyst, owing to the want of that barrier of lymph which is effused in common phlegmon. These abscesses are often numerous, but insulated and distinct from each other: at other times they occupy a great extent, and contain a large quantity of pus, often mixed with shreds of mortified membrane. In the more severe forms of this affection the natural organization is in some places totally destroyed, and the cellular substance, from the effects of gangrene, is converted into a greyish or dark-coloured slough.

These changes are not confined to the subcutaneous membrane, in which, however, they are principally observed, but are seen in the cellular sheaths of the muscles, and even in the processes which separate their different fasciculi. The muscles themselves, under these circumstances, partake in the disorganization, and lose their proper colour.

The progress of this formidable disease would seem to shew that an acrid and irritating humour is effused into the cellular substance, where it rapidly causes suppuration and sloughing, in the same manner as when urine is extravasated into the perinæum and scrotum. That a vitiated state of the blood is often produced is a now well-known fact, and such a condition appears to be induced in the disease under consideration, either in consequence of the introduction of a poison into the system, as from the bite of a venomous serpent, or from a deterioration of the constitution, as in draymen, coal-porters, and others, who in large towns consume enormous quantities of fermented liquors; or, lastly, from both these causes combined, as from punctures received in dissection by individuals who at the time are in an indifferent state of health.

II. Infiltration, *or effusion.*—The escape of various fluids from their proper receptacles into the cellular tissue is of extremely frequent occurrence.

a. Blood.—This is effused either as a consequence of external violence acting on the arteries and veins, or from an internal cause, of which the nature is more obscure. When the hemorrhage is extensive, the surrounding tissue is unable to resist the progress of the blood, and the infiltration becomes of considerable extent. It is by effusions of this kind that *ecchymoses, false aneurisms*, &c. are formed.

b. Serum.—A very common morbid change is the infiltration of a thin watery fluid into this tissue, consisting of an accumulation of the serum naturally exhaled into its cells. The effused fluid, apparently owing to its containing a larger proportion of albumen than usual, is occasionally of a more viscid nature, so as

* Compend. of Pathol. Anat. by South, vol. i. p. 91.

to escape but imperfectly on a puncture being made; and in other cases, as in the diffused swelling so often occurring in bad constitutions after serious local injury, compound fractures, poisoned wounds, &c. the effused fluid is of an acrid character. The effusion is often restricted to a particular region, *(œdema;)* at other times it is more extensive, and may even occur in all parts of the body *(anasarca)*. In all instances in which effusion takes place, it ought to be regarded simply as an effect, resulting from some previous change in the vessels of the cellular tissue, which stands in the relation of a cause. This change consists, I believe, in the great majority of cases, if not in all, in a preternatural congestion of the bloodvessels, which may be induced by inflammation, debility, mechanical obstruction to the free return of the venous blood, or the suspension of any of the great secretions of the body.

c. Air.—Emphysema, in its usual form, arises from an unnatural communication being formed between some part of the air-passages and the cellular tissue *(traumatic emphysema)*: it is thus an occasional consequence of fracture of the ribs, in which the neighbouring portion of the lung is lacerated; of penetrating wounds of the chest; of rupture of the air-cells by violent exertions; of ulceration of the air-cells; of rupture of the membrane of the larynx, and even of the lachrymal sac and windpipe, and of fractures in the vicinity of the frontal sinuses, causing a laceration of their mucous membrane. Emphysema has been likewise known to arise spontaneously, the air appearing to be secreted from the bloodvessels; and it is also a frequent attendant on gangrene, in which case the effused air is the result of the decomposition of the fluids previously collected.

d. Urine.—Effusion of urine may arise from a wound or ulceration of any of the organs through which the urine passes; usually, however, it is a consequence of an injury of the bladder or urethra. The accident particularly demands notice on account of the destructive effects which result from it. These effects are extensive mortification of the cellular tissue, and, in a somewhat less degree, of the skin, followed by profuse suppuration, attended with constitutional symptoms of so serious a nature as often to cause the death of the patient.

III. Induration.—Induration occurs as a special disease in new-born infants, and in a large proportion of those who are attacked, there is a fatal termination from the sixth to the thirtieth day; in very severe cases, and in infants prematurely born, death may take place in two, three, or four days. Some idea of the mortality in this disease may be formed from the following facts: in the Foundling Hospital in Paris, the mortality of late years has been one in three; out of twenty-seven cases occurring in 1809, at La Charité in Berlin, only two were saved; in fifteen cases seen by Lobstein, four recovered.

The disease is very prevalent in the large foundling hospitals on the continent, as many as 240 cases occurring in one year in the Hospice des Enfans Trouvés of Paris, out of 5392 received into the institution. In this country, where, fortunately for humanity, no such establishments exist, and where consequently new-born infants are but rarely deserted by the mother, the disease is very rare. Dr. Copland states that he has not met with an instance of it in the Queen's Lying-in Hospital, and that even in the Infirmary for Children, such cases are very rarely presented. I have made inquiries of several very extensive practitioners of midwifery, some of whom are connected with public institutions, and they have very rarely or never seen the disease.

The parts which are attacked, usually the legs, hands, and face, are more or less swollen, hard, and rigid to the touch; and the skin assumes a red or violet colour in consequence of the respiration being imperfectly performed. The affection consists of an œdematous state of the cellular tissue, the areolæ being loaded with a concrete albuminous matter and a sero-sanguineous fluid, which oozes out when a section is made and quickly coagulates; it is this infiltration that is the cause of the peculiar hardness, for according to M. Billard, who has carefully investigated the characters of the disease, the cellular fibres and layers preserve all their flexibility, and present no signs of having undergone any organic change. According to M. Chevreul, in this disease the serum of the blood contains an abundant quantity of a matter distinct from fibrin, but which spontaneously coagulates; this substance is perfectly identical with the material to which the cellular tissue owes its apparent induration.

The history of this disease, and the results obtained by dissection, prove that venous congestion is a very constant morbid appearance; and it is a question that has not hitherto been decided, how far this congestion is the exciting cause of the disease.

IV. Morbid growths. — These are of very common occurrence and of very various characters; some consisting of the transformation of the cellular membrane into other tissues, the fibrous and osseous for example; whilst others are entirely new productions, and occasionally prove of a malignant nature, such as cysts, vascular sarcoma, scirrhus, melanosis, &c. We do not often meet with bony or fibrous formations in the common cellular structure, although I have occasionally seen growths with these characters. From an examination of many specimens, I am induced to believe that the ossific deposits not unfrequently observed in connection with the fibrous and serous membranes, as the dura mater, pleura, &c. are formed in the cellular tissue of these structures.

V.—Foreign bodies are sometimes introduced into the cellular tissue from without, such as bullets, needles, &c. Certain parasitic animals, the origin and characters of which are very obscure, are also occasionally met with in the substance of the human body, and especially in the cellular tissue. At the present day it is generally admitted that hydatids are bodies endowed with vitality, the most common species of which is the *acephalocyst;* another species is the *cysticercus cellulosus.* The *filaria medinensis,* or guinea-worm, is another parasitic animal which has been seen in the human body.

Lastly, the cellular tissue may vary in the degree of its consistence, colour, &c.; and owing to some derangement in the function of nutrition, it may present a preternatural increase or a wasting of its substance: *(hypertrophy or atrophy.)*

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(R. D. Grainger.)

CEPHALOPODA—(κεφαλη, *caput,* πους, *pes);* Eng. *Cephalopods;* Fr. *Céphalopodes;* Germ. *Kopffüsslern, Blackfische, Tinten-fische;* Ital. *Seppie, Polpi. Syn.* Μαλακία, Aristotle; *Mollia,* Pliny; the genera *Nautilus, Argonauta,* and *Sepia,* Linné; *Octopodia,* Schneider; *Mollusca brachiata,* Poli; *Mollusca Cephalopoda,* Cuvier; *Cephalopoda,* Lamarck, Leach; *Brachiocephala, Céphalophores,* De Blainville; *Pterygia,* Latreille, (including the Pteropoda of Cuvier); *Antliobrachionophora,* Gray.

Definition.—A class of Molluscous Invertebrate animals in which the *head (A, figs.* 206, 209,) is situated between the *trunk* (*B*) and the *feet* (*C*), or principal organs of locomotion.

Characters of the Class.—The *trunk* or body is thick and soft; varying in form from a sphere, to a flattened ellipse, or elongated cylinder; sometimes protected by a shell, sometimes naked; consisting of a membranous or muscular sheath or *mantle,* with a transverse anterior* aperture (*a, figs.* 206, *et seq.*) and containing the respiratory, circulating, generative, and principal digestive viscera: the mantle sometimes supports a pair of fins (*b, figs.* 207, 208, 209,) and, in the naked species, lodges in its substance the rudiments of a shell.

The *head* is distinct from the trunk, of large size, and of a rounded figure; it contains the organs of sense, mastication, and deglutition, and gives off from its anterior circumference or external surface, a number of fleshy processes which encircle and more or less conceal the mouth.

These processes, by some naturalists termed the *feet,* but which we prefer to call, with Poli, the *arms,* are either very numerous, short, and hollow, containing each a long, slender retractile tentacle *(figs.* 205, 213); or they are eight *(figs.* 206, 210), or ten *(figs.* 207, 208), in number, solid, supporting on their internal surface numerous suckers *(antlia, acetabula);* and being more or less elongated and flexible in every direction, they act as powerful organs of adhesion, prehension, and locomotion.

The *eyes* are a single pair, of large size, varying in relative perfection of structure according to the locomotive powers of the species, and either pedunculated or sessile.

The *mouth* is anterior, and situated at the bottom of the conical cavity formed by the base of the feet; it is provided with two horny or calcareous jaws, shaped like the mandibles of a Parrot, playing vertically on each other, and inclosing a large fleshy tongue, which is armed with recurved horny spines.

The *branchiæ* are concealed within the mantle, and are symmetrical in size, form, and position. The systemic circulation is aided by a muscular ventricle.

The *infundibulum,* (*i, figs.* 206, 208,) or passage through which the respiratory currents and the excrements are discharged, is a muscular tube, situated at the anterior part of the neck, shaped like an inverted funnel, with the pipe projecting from the visceral cavity, and directed forwards.

The *sexual organs* are separate and exist in distinct individuals; but whether impregnation takes place by copulation or after the ova are excluded is not determined; the former is most probable.

All the species are aquatic and marine.

Division of the Class into Orders.— The type of organization which characterizes the Cephalopods, and of which the preceding is a general outline, presents two principal modifications, according to which the class is divided into two orders.†

* Throughout the present article the terms of aspect and position relate to that in which the animal is represented in *fig.* 206. The shell covers the *posterior* part of the body, the arms are *anterior* and directed forwards; the letters *A, B, C,* are along the *dorsal* or upper surface, the letter *i* is beneath the *ventral* or lower surface.

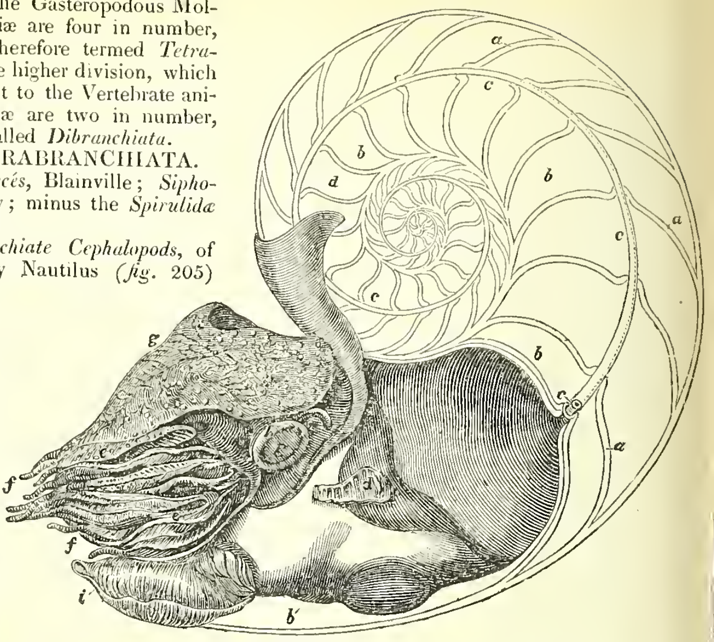
† A third order of Cephalopods (the *Cellulacea* of De Blainville) has been proposed to include an extensive series of minute polythalamous shells, of exquisite beauty in their form and sculpture, which differ from the camerated shells of our Tetrabranchiate order in the absence of a siphon, but which

In the first of these, which is most closely allied to the Gasteropodous Mollusks, the branchiæ are four in number, and the order is therefore termed *Tetrabranchiata:* in the higher division, which approaches nearest to the Vertebrate animals, the branchiæ are two in number, and the order is called *Dibranchiata*.

Order I. TETRABRANCHIATA. Syn. *Polythalamacés*, Blainville; *Siphonifera*, D'Orbigny; minus the *Spirulidæ* and *Belemnitidæ*.

The *Tetrabranchiate Cephalopods*, of which the Pearly Nautilus (*fig.* 205) may be regarded as the type, are provided with a large external univalve shell, symmetrical in form like the body of the animal which it protects, straight, or convoluted on a vertical plane, and divided by a series of partitions (*a, a*) into numerous chambers (*b, b*), of which the last-formed (*b'*) is the largest, and alone contains the body of the animal: a dilatable and contractile tube (*c, c*) is continued from the posterior part of the animal through all the partitions and chambers of the shell; but the attachment of the shell to the body is effected by means of

Fig. 205.



The Pearly Nautilus, *Nautilus Pompilius*, Linn.

M. D'Orbigny believes to be constructed by molluscous animals of a grade of organization which entitles them to rank with the Cephalopodous class. For this group of animals M. De Haan has proposed the name of *Asiphonoidea;* but M. D'Orbigny, observing that the chambers of their shells communicate together by means of one or more foramina, has substituted the positive term *Foraminifera*, and they are placed by Cuvier at the end of the Cephalopodous class under that denomination in the last edition of the Règne Animal.

Strong evidence has, however, been recently adduced to prove that these minute shells owe their existence to animals which have no pretensions to rank with the Cephalopods; but before we give the account of M. Dujardin, who is the author of this view, we shall first quote M. D'Orbigny's own description of the animal of the shells, the structure of which he has so ably studied and so happily demonstrated by means of enlarged models.

"The Cephalopods of the Foraminiferous Order have a bursiform body, in the posterior part of which the shell is lodged; the body of the animal sometimes presents a great size compared to that of the head, to which it is occasionally subservient as a means of protection, entirely surrounding it in the anterior folds of the skin. The head is small, scarcely, if at all, distinct from the body, terminated by numerous tentacles forming many rows around the mouth, which is central. The animal seems to adhere very slightly to the shell; it rapidly passes into a state of decomposition after death, when the slightest touch is sufficient to detach it from the shell, in which nothing is left but a coloured liquid which fills all its chambers. The food of these animals consists of different species of Polyps."

M. De Blainville, however, states, in the Appendix to his Manuel de Malacologie, *page* 649, that the animal of one of the microscopic genera contained in his order Cellulacea, viz. ***Miliola***, has no relation whatever in its structure to a Cephalopod, or *Cryptodibranche*. And more recently M. Dujardin has read a memoir, entitled '*Sur les Symplectomères, ou pretendus Cephalopodes microscopiques*,' in which the results of numerous and apparently careful observations on the soft parts of different genera of the animals in question are directly opposed to those of M. D'Orbigny.

M. Dujardin carefully studied the Miliolæ, Vorticialiæ, Rotaliæ, Truncatulinæ, Cristellariæ, Melloniæ, &c. in the recent and living state; and found that the shell was not internal, and that the animal, which is absolutely deprived of organs of locomotion and even of respiration, is composed of a succession of joints or lobes, which go on increasing successively, and enveloping each other. The only period when the soft parts of the animal are visible externally, is when a new joint is produced which has not completed the formation of its chamber. On breaking the shell, the composition of the animal is found to be as simple as in the Planariæ or Hydræ, or any other animals of the Acrite sub-kingdom; and on dissolving the shell by means of a mixture of alcohol and very weak nitric acid, the entire body is obtained, which is formed of a succession o[f] articulations, occupying all the chambers; an[d] presenting different aspects in different genera which accord with the peculiarities of the shell.

From these observations it necessarily follow[s] that the *Foraminifera* of M. D'Orbigny cannot b[e] arranged with the Cephalopods, or even placed i[n] the Molluscous Series. M. Dujardin, therefore proposes to consider them as a distinct class o[f] Invertebrata, under the name of *Symplectomères* and until further and better evidence be adduce[d] to the contrary, we shall regard these minute ani[-]mals as having only, in the form and structure [of] their shells, a remote analogical relation to th[e] Cephalopods.

two strong lateral muscles (d^*), which are inserted into the walls of the last chamber. The numerous ~~hollow~~ arms (e, e) and retractile tentacles (f, f), mentioned in the general characters of the class are peculiar to this order, and the head is further provided with a large ligamento-muscular plate, or flattened disc, (g,) which, besides acting as a defence to the opening of the shell, serves also, in all probability, as an organ for creeping along the ground, like the foot in the Gasteropods. There are no fins or analogous organs for swimming.

The *jaws* of the *Tetrabranchiata* are strengthened by a dense, exterior, calcareous coating, and have thick dentated margins.

The *eyes* are pedunculated (h, *fig.* 205) and of a simple structure.

There is no organ of hearing.

The gills are four in number, and without branchial hearts.

The circulating system is provided with but one ventricle, which is systemic or propels arterial blood.

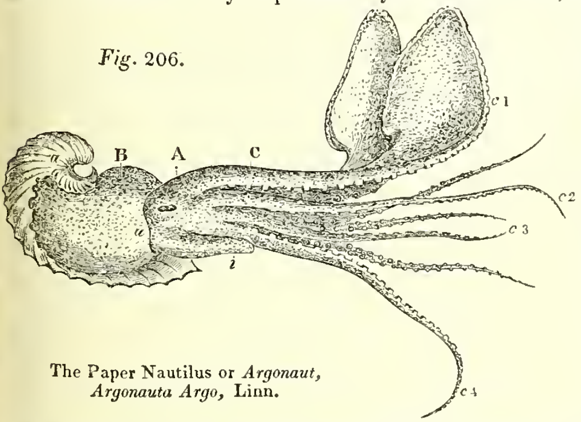
There is no ink-bag.

The inferior parietes of the *funnel* (i, *fig.* 205) are divided longitudinally.

Order II. DIBRANCHIATA. Syn. *Cryptodibranches*, Blainv.; *Acetabulifera*, D'Orb.; plus the *Spirulidæ* and *Belemnitidæ*.

In the *Dibranchiate Cephalopods* one genus alone (*Argonauta*, *fig.* 206) has been hitherto found in which the body is protected by an external shell (a); but this, though symmetrical, and convoluted on a vertical plane, consists of one simple chamber, or is 'monothalamous,' and does not adhere to the body of its Cephalopodous occupant, either by a hydraulic pipe or lateral muscles. All the other genera of the Dibranchiate Order are naked; but they are provided either with an internal siphoniferous polythalamous shell,† or the remains of a shell are found in various stages of degradation lodged in the substance of the dorsal part of the mantle.

Fig. 206.



The Paper Nautilus or *Argonaut*, *Argonauta Argo*, Linn.

The *arms* of the Dibranchiata are, properly speaking, eight in number, (c, 1, 2, 3, 4, *fig.* 206,) to which, in many genera, two longer *tentacles* (d, d, *figs.* 207, 208) are superadded. Both kinds of prehensile organs are provided with acetabula, or suctorious discs for adhesion; and hence the order has been termed *Acetabulifera.*

The *jaws* are horny, and their margins trenchant.

The *eyes* are sessile, (e, e, *fig.* 207,) and of a more perfect structure.

The organ of hearing is distinctly developed.

The *gills* never exceed two in number; but the branchial circulation is aided by two muscular ventricles, situated one at the base of each gill; hence there are three distinct hearts in this order.

There is an organ for secreting and expelling an inky fluid, used as a means of concealment.

The parietes of the *funnel* are entire, (i, *figs.* 206, 208.)

Subdivision of the Orders.—In the ancient periods of the globe the Tetrabranchiate Cephalopods appear to have abounded in every sea; one genus only, however, viz. the Nautilus, appears to have escaped the influences which have rendered extinct the rest of this once extensive order. Their chambered shells are found, generally in a fossil state, in all the regions of the globe, and at every elevation, characterizing the strata of the secondary formation. In some places they occur in such prodigious numbers that the rocks appear to be composed almost exclusively of their remains.

Some of these fossil shells testify the immense size to which their animal constructors must have attained: the shells called 'Cornua Ammonis,' which were formed by Cephalopods resembling the Nautilus, have been found measuring four or five feet in diameter; some of the straight chambered shells, called 'Orthoceratites,' exceed four feet in length; other species again appear not to have surpassed the size of a grain of rice.

As the consideration of these remains, of which the Tetrabranchiate division of Cephalopods is almost exclusively composed, would necessarily oblige us to exceed the limits allotted to this article, we shall here subjoin merely the characters of the two families into which they naturally resolve themselves, and to which their distribution appears to be limited.

* The letter is placed on the portion of broken shell which still adhered to one of the lateral muscles in the specimen taken by Mr. Geo. Bennett, in the New Hebrides Islands. See Pl. 1. *Memoir on the Pearly Nautilus*, 4to. 1832.

† This is the case in the Families *Spirulidæ* and *Belemnitidæ*; the terms *Polythalamacea* or *Siphonifera*, therefore, do not distinguish the preceding or Tetrabranchiate Order, nor indicate any characters peculiar to that group, or which are of ordinal importance: and in other Molluscous classes it may be observed that modifications of the shell fail to afford indications of the primary divisions, which are uniformly based, as in the present arrangement of Cephalopods, on the modifications of the respiratory system.

Fam. 1. *NAUTILIDÆ*, Nautilites.

Animal, organized as described in the character of the order.

Shell external; spiral, or straight; septa smooth, and simple; the last chamber the largest, and containing the animal: siphon central, or marginal and internal.

Ex. GENERA *Nautilus*, Lamarck; *Clymenes*, Munster; *Campulites*, Deshayes; *Lituites*, Breyn; *Orthoceratites*, Breyn.

Fam. 2. *AMMONITIDÆ*, Ammonites, Snake-stones.

Animal unknown, presumed to resemble the Nautilus.

Shell external; spiral or straight; septa sinuous, and with lobated margins; the last chamber the largest and lodging the animal: siphon central, or marginal and exterual.

Ex. GENERA *Baculites*, Lamarck; *Hamites*, Parkinson; *Scaphites*, Parkinson; *Ammonites*, Bruguière; *Turrulites*, Lamarck.

The Dibranchiate Order of Cephalopods also had its representatives in the seas of the ancient world, as the shells called *Belemnites*, or thunder-stones, the fossil shells of the Sepiæ discovered by Cuvier, and the horny rings of the acetabula found by Buckland in the fossil fæces of Ichthyosauri, sufficiently testify; but our knowledge of this order is chiefly founded on observation of existing species. These are extremely numerous; they frequent the seas of every clime, from the ice-bound shores of Boothia Felix to the open main, and floating Sargasso or gulf-weed of the Equator; they seem, however, to be most abundant in temperate latitudes. Many species frequent the coasts, creeping among the rocks and stones at the bottom; others are pelagic, swimming well, and are found in the ocean at a great distance from land.

The *Dibranchiata* present great variety of size, and although the bulk of the gigantic species has been undoubtedly exaggerated, yet the organization of this order is favourable to the attainment of dimensions beyond those presented by the individuals of any other group of Invertebrate animals. The remains of the large Uncinated Calamary caught by Banks and Solander in the Southern Ocean, parts of which are still preserved in the Hunterian Museum, and the fragment of the Cephalopod weighing one hundred pounds, taken by the French naturalists in the Atlantic Ocean under the line, and preserved in the Museum of the Garden of Plants at Paris, afford indubitable testimony of the formidable size to which some individuals of this order attain.

The species included in the higher division of Cephalopods very naturally resolve themselves into those which possess the eight ordinary arms, forming the tribe *Octopoda*; and into those which have the additional pair of elongated tentacles, forming the tribe *Decapoda*.

The Decapods are further characterized by having a pair of fins attached to the mantle; by having the funnel either adherent at the antero-lateral parts of its base, and without an internal valve, or articulated at the same part by two ball-and-socket joints to the mantle, and provided with a valve internally at its apex; by having fleshy appendages to the branchial hearts, and glandular appendages to the biliary ducts; by having generally a single oviduct, with detached superadded glands; and, lastly, by the shell or its rudiment being single, mesial, and dorsal.

The Decapodous tribe is that which is most nearly allied to the Tetrabranchiate Order. This affinity is not only indicated by the additional number of external arms, and the frequent development of an internal circular series of eight short labial tentacles, but by several internal characters; as the single oviduct and detached glands for secreting the nidamentum; the valve of the funnel; the laminated rudiment of a chambered shell in the Cuttle-fish, and the fully developed chambered and siphoniferous shell of the *Belemnites* and *Spirula*. The observations of Peron and Lamarck having proved that the animal of the *Spirula* possesses eight short arms and two long tentacles, all provided with acetabula, like the *Sepia*, we regard it as the type of the first family of the Decapodous Tribe, or that which immediately succeeds the *Tetrabranchiata*.

Tribe DECAPODA.

Fam. 1. *SPIRULIDÆ*.

Animal, corresponding in external form to the Decapodous type; internal organization unknown, presumed to be Dibranchiate.

Shell partly internal; cylindrical, multilocular, discoid; the whorls separated; septa transverse, concave next the outlet, and with regular intervals.

Siphon marginal and internal, uninterrupted.

Genus SPIRULA, Lam.

The character of the family is also that of the single genus of which it is at present composed.

Ex. *Spirula Australis*, Lam.

Fam. 2. *BELEMNITIDÆ*, Belemnites, Thunder-stones.

Animal unknown.*

Shell internal, composed of an external calcareous sheath formed by a succession of hollow cones, the exterior being the largest; of an internal horny sheath, also of a conical form, containing at its apex a chambered shell, the septa of

* As it is certain that the animals of this family of extinct Cephalopods possessed the ink-bag, they must consequently have been enveloped by a muscular mantle; and we may, therefore, infer that they resembled the Dibranchiates in their locomotive and respiratory organs, and consequently in the general plan of their organization. In the structure and position of their siphoniferous camerated shell they are intermediate to *Spirula* and *Sepia*, and as the animal of *Spirula* is proved to be a Decapod, the probability is very strong that the animal of the Belemnite was of the same type.

which are concave externally and perforated by a marginal and ventral siphon.

Genus BELEMNITES, Lamarck.*

Fam. 3. *SEPIADÆ*, Cuttle-fishes.

Animal, body oblong, depressed, with two narrow lateral fins extending its whole length.

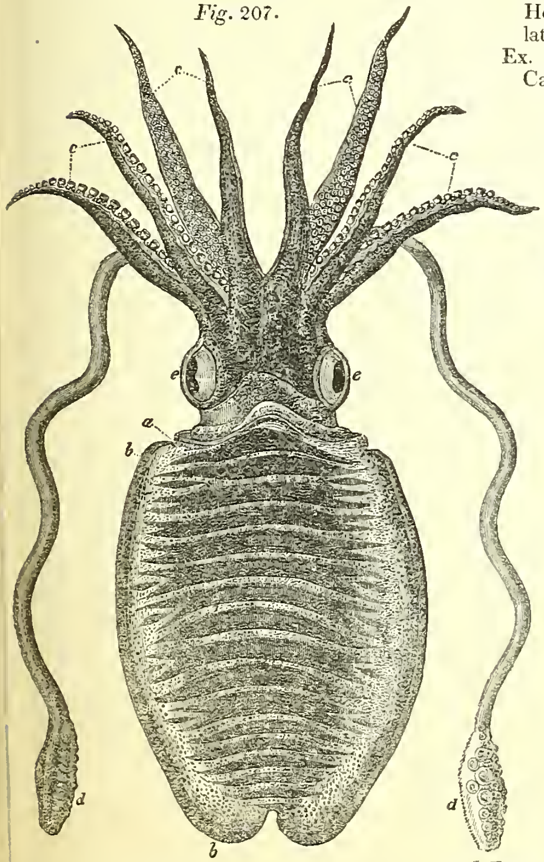
Shell internal, lodged in a sac in the back part of the mantle, composed of an external calcareous apex or mucro, of a succession of calcareous laminæ with intervening spaces filled with air, and supported by columns, but not perforated by a siphon, and an internal horny layer, corresponding to the anterior horny sheath of the Belemnites.

Genus SEPIA, Cuv.

The character of the family is also that of the single genus at present composing it; we may, however, add under this head that the mantle is free at its anterior margin; and that the acetabula are supported by horny hoops with the margin entire, or very minutely denticulated.

Ex. *Sepia officinalis*, Linn. the common Cuttle-fish. (*Fig*. 207.)

Fig. 207.



Fam. 4. *TEUTHIDÆ*,* *Calamaries.*

Animal, body sometimes oblong and depressed, generally elongated and cylindrical; with a pair of fins varying in their relative size and position, but generally broad, shorter than the body, and terminal.

Shell internal, rudimental, in the form of a thin, straight, elongated, horny lamina; encysted in the substance of the dorsal aspect of the mantle.

A. Funnel with an internal valve, and articulated at its base to two ventro-lateral cartilaginous prominences of the mantle.

Genus SEPIOTEUTHIS, Blainville.

Body oval, flattened, with narrow lateral fins, extending its whole length; anterior margin of the mantle unattached. Horny hoops of the acetabula with denticulated margins. *Gladius*, or rudimental shell, long and wide.

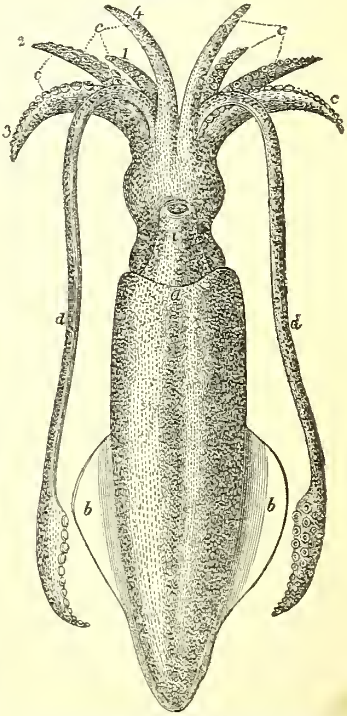
Ex. *Sepioteuthis loliginiformis*, Ruppel.

Genus LOLIGO, Cuvier.

Body elongated, cylindrical, provided with a pair of rhomboidal or triangular fins, shorter than the body, and terminal, their apices generally converging to a point, and united to the end of the mantle; anterior margin of the mantle free. Horny hoops of the acetabula denticulated. *Gladius* long and narrow.

Ex. *Loligo vulgaris*, Cuv. the common Calamary or Pen-fish. (*Fig*. 208.)

Fig. 208.



The Calamary, *Loligo vulgaris*, Cuv.

* Also the fossil genera, *Actinocamax*, Miller; *Pseudobelus*, Blainville.

* From the term τευθος applied by Aristotle to the ten-armed Malakia with an internal horny plate or *gladius*.

Genus Onychoteuthis, Lichtenstein. Body and fins as in the genus *Loligo;* ventro-lateral cartilages of the mantle long and narrow; horny hoops of the tentacular, and sometimes of the brachial, acetabula produced into the form of hooks or claws. (*Fig.* 215.) *Gladius* long, broadest in the middle.

Genus Rossia, Owen. Body short and rounded; cephalic margin of the mantle free; fins advanced, short, circular, sessile, distant and subdorsal. *Gladius* short and narrow.

Ex. *Rossia palpebrosa*, Owen.

Genus Sepiola, Leach. Body rounded, short; anterior margin of the mantle adherent to the back of the head; fins advanced, circular, short, subpedunculate, distant and subdorsal. *Gladius* short and narrow.

Ex. *Sepiola Rondeletii*, Leach.

B. Funnel unprovided with an internal valve, and adherent at the antero-lateral parts of its base to the mantle.

Genus Loligopsis, Lamarck.

Body long and cylindrical, terminated by a pair of conjoined large round fins, forming generally a circular disc; anterior border of the mantle adherent to the back part of the head for a small extent. *Tentacula* very long and slender, (frequently mutilated.) *Gladius* long, narrowest in the middle, dilated posteriorly.

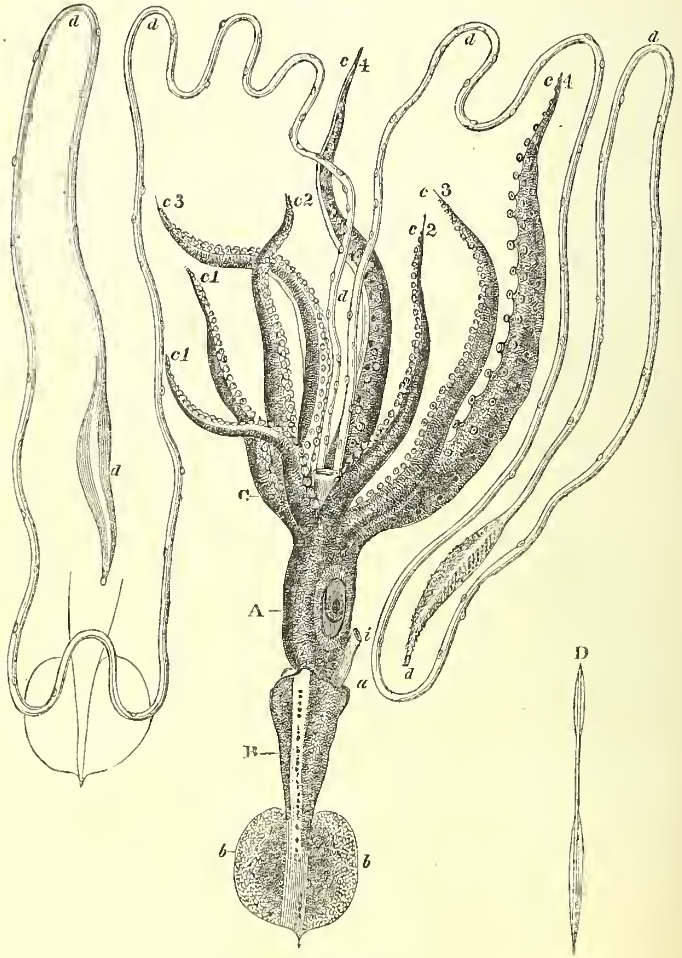
Ex. *Loligopsis Veranii*, Férussac. (*Fig.* 209; D the gladius or rudimental shell.)

Genus Cranchia, Leach. Body elongated, sacciform; anterior margin of the mantle adherent to the back of the head. Fins short, rounded, subpedunculate, approximate, dorsal, and subterminal. *Gladius* long and narrow.

Ex. *Cranchia scabra*, Leach.

Tribe OCTOPODA. The Dibranchiate

Fig. 209.



Loligopsis Veranii.

Octopods, besides wanting the long tentacula, are also characterized by the absence of mantle-fins, and consequently are limited to retrograde progression while swimming; their acetabula are sessile and unarmed; they have two oviducts, but without detached glands for secreting a nidamentum.

Family *TESTACEA*.

Body oblong, rounded; mantle adhering posteriorly to the head; first, or dorsal pairs of arms dilated and membranous at the extremity; (*c*, 1, *fig.* 206.) *Funnel* without a valve, but articulated at its base by two ball-and-socket joints to the inner sides of the mantle. Branchial hearts with fleshy appendages. No internal horny or testaceous rudiments; but an external monothalamous, symmetrical shell, containing, but not attached to, the body of the animal; which also deposits its eggs in the cavity of the shell.

Genus ARGONAUTA, Linnæus. On the supposition that the shell is parasitically occupied by the Cephalopod, but formed by some other mollusk, some naturalists limit the above generic title to the shell, and call the Cephalopod *Ocythoë*.* We shall, however, continue to apply the term *Argonauta* to the Cephalopod in question, as the evidence, though strong, is not conclusive of its parasitic nature. The character of the Family is also that of the Genus.

Ex. *Argonauta Argo*, Linn. (*fig.* 206.).

Genus Belerophon, founded on the fossil remains of a shell resembling in family characters that of the *Argonauta*.

Ex. *Belerophon apertus*, Sowerby.

Family *NUDA*.

Body generally rounded, mantle broadly continuous with the back of the head. Arms connected at the base by a broad web: first pair elongated, and gradually narrowing to a point. Funnel without an internal valve or external joints; branchial hearts without fleshy appendages; biliary ducts without follicular appendages. Shell represented by two short rudimental styles, encysted in the dorso-lateral parts of the mantle.

Genus OCTOPUS, Leach. The arms provided with a double alternate series of sessile acetabula.

Ex. *Octopus vulgaris*, Cuv. the Poulp or Preke, (*fig.* 210, in which this species is represented in the act of creeping on the shore; its body being carried vertically in the reverse position with the head downwards; its back being turned to the spectator, towards whom it is supposed to be advancing.)

Fig. 210.

The Poulp, *Octopus vulgaris*, Cuv.

* Should the above suspicion be proved to be well founded, we conceive that it would be more appropriate to retain the term *Argonauta*, in order to designate the Cephalopod which navigates the frail bark; and revert to the original name of *Cymbium* for the shell, which was applied to it by

Genus Eledone, Leach. The arms provided with a single series of sessile acetabula.

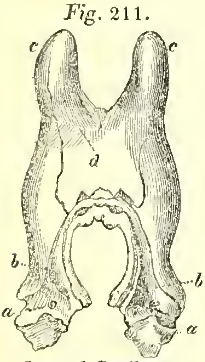
Ex. *Eledone cirrosa*, Leach.

Internal cartilaginous parts, or Endoskeleton.—In the Gasteropodous Mollusks the cerebral or supra-œsophageal ganglions are protected by a dense membrane which has been compared to a dura mater, but which may be regarded with more propriety as representing the membranous condition of the skull in the embryo of the vertebrate animal; and which, in fact, assumes a cartilaginous texture in some of the higher organized *Pectinibranchiata*, forming in them the unquestionable rudiment of a true internal skeleton.

In the present class a thick cranial cartilage not only protects the cephalic masses of the nervous system; but it is enlarged and extended in different directions, so as to afford a basis of attachment to the principal muscular masses of the body: thus fulfilling the second important function of an internal skeleton.

In the Nautilus it consists of one principal cartilage, (*fig.* 211,) which is situated on the ventral aspect of the œsophagus; two processes (*a a*) extend from the posterior or dorsal angles on each side of the œsophagus as far as the optic ganglions. A deep semicircular groove (*b*) extends along the anterior part of these processes for the lodgment of the optic ganglions and the anterior nervous collar surrounding the œsophagus. Two other processes (*c c*) arise from the ventral angles of the cartilage and give support to the sides of the base of the funnel. A middle process is extended some way between the two great muscles which are inserted into the shell. The central part or body of the cartilage (*d*) is excavated for the reception of the venous blood returned from the head and funnel, and from this sinus the great dorsal vein commences.

Fig. 211.



Internal Cartilage or Skeleton of the Nautilus.

In the Dibranchiate Cephalopods the internal cartilaginous skeleton consists of a greater number of pieces, and has a more important share in the organization and functions of the animal. We shall describe it principally as it exists in the Cuttle-fish (*Sepia Officinalis*).

The cranial cartilage (A, *fig.* 212) is no longer limited in its position to the under side of the œsophagus, but completely surrounds that tube, which, together with the inferior salivary ducts, and the cephalic branches of the aorta, traverses a narrow passage in the centre. It is expanded above into a cavity, which encloses and protects the brain; while, below the œsophagus, the dense cartilage is excavated to form the two vestibular cavities of the organ of hearing; at the sides it is developed into broad and thick concave processes, which form the back part of the orbits.

In the subjoined figure A is the cranial cartilage as seen from above:—

a is the superior part which protects the brain.

b, *b*, are the two large optic foramina.

c, *c*, the posterior and inferior thick expanded orbital process.

d, *d*, the thin and long anterior and inferior cartilage which supports the eye-ball, and is analogous to the cartilaginous eye pedicle of the Rays and Sharks: these processes are compared by Meckel to the superior maxillæ; they do not exist in the Octopods, and are comparatively much smaller in the Calamaries than in the Cuttle-fish.

e, the anterior aperture of the canal through which the œsophagus passes.

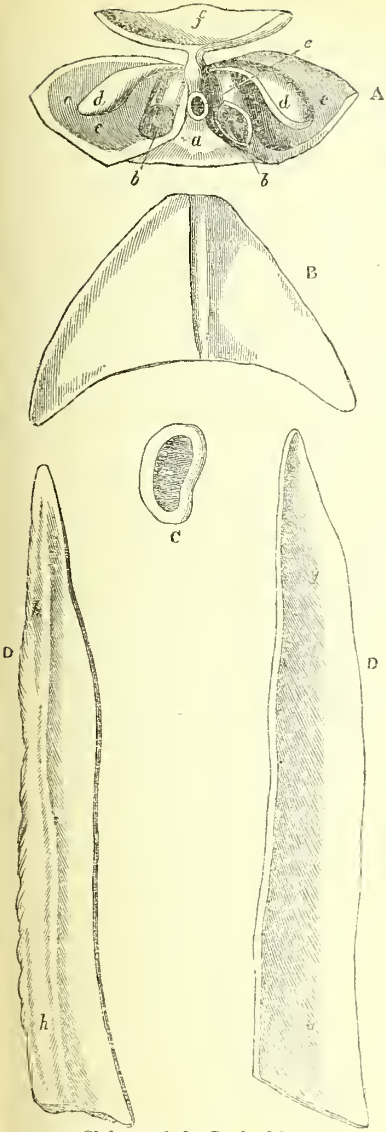
f, a process, continued from the anterior part of the cranial cartilage, which expands into a broad transverse plate, with a slight concavity directed forwards, and gives attachment to the muscles of the arms: this cartilage Meckel compares to the lower jaw, but the analogy is not more satisfactory than in the preceding instance.

The infundibular or nuchal cartilage (B), which is a process of the cranial cartilage in the Nautilus, is in the Dibranchiates, and especially the Cuttle-fish, a distinct piece, of large size, and of a flattened triangular figure, situated above the base of the funnel, with its apex directed forwards and its posterior angles turned backwards: it has a moderately deep furrow along the middle of its upper surface. In the Sagittated Calamary this important cartilage consists of three portions, a middle elongated one, having on its dorsal surface a mesial longitudinal groove, and two lateral longitudinal ridges which are adapted to a corresponding ridge and two grooves in the under part of the sheath of the gladius, which sheath here assumes a dense cartilaginous consistence: from the anterior extremity of the middle nuchal cartilage two flattened cartilages extend outwards and backwards, and then curve slightly inwards. These correspond to the dilated base of the cartilage in the Sepia, protect the great lateral nerves of the mantle, and give origin to the lateral muscles which are perforated by the nerves.

On each side of the base of the funnel there is a smooth oblong articular cavity which is formed by a distinct cartilage (C); it is adapted to receive a corresponding cartilagi-

Gualtieri, when he first separated it generically from the Chambered Nautilus. In either case, as the grounds for constituting the new family of Octopoda now proposed are derived from important organic differences, as manifested in the structure of the funnel and the branchial hearts, the claims of the Cephalopod to form the type of such a group would not be destroyed by the proof of the shell forming no part of its structure. We cannot, however, retain both the genera Argonauta and Ocythoë, as in the *Familles Naturelles du Règne Animal* of Latreille, p. 168; since, if the shell in question be not secreted by the Cephalopod, its analogy to that of the Carinaria would indicate its real constructor to belong to the Heteropodous Mollusks.

Fig. 212.



Skeleton of the Cuttle-fish.

ous prominence arising from the inner surface of the sides of the mantle. This prominence in the *Sepia* is of an oval shape; but the *Teuthidæ* it forms a narrow, elongated, rtilaginous ridge, and is adapted to a corsponding groove at the sides of the funnel. the Calamary the ridge is of the same size th the groove; but in the Onychoteuthis the lge or antero-lateral cartilage commences at e anterior margin of the mantle, and extends wnwards some way below the termination of e infundibular groove. Rathké* discovered the corresponding part of the mantle of the Loligopsis, viz. on either side and towards the ventral aspect, a thick, opaline, elongated cartilage, extending longitudinally for more than half the length of the mantle, and supporting a series of wart-like processes. These lateral tuberculated cartilages in *Loligopsis* we regard as corresponding to the lateral ridges in the Calamaries and Onychoteuthis above-mentioned; but in the *Loligopsis* they are not articulated with the sides of the funnel, which are otherwise attached to the mantle. In all the Decapods, however, this pair of cartilages on the ventro-lateral aspects of the mantle is more or less developed.

In the Sepia a longitudinal cartilage is situated on the ventral aspect of the liver. The long lateral fins are, in the same genus, each supported by a narrow, flattened, elongated, cartilaginous plate (D, D, *fig.* 212); pointed at its anterior extremity, obliquely truncate behind; smooth and gently concave internally *(g)*, but traversed by an irregular longitudinal ridge *(h)* on its external surface. These cartilages form the points of attachment to the powerful muscles of the lateral fins. From the dorsal ridge of each cartilage a number of close-set fibro-cartilaginous laminæ extend at right angles to the cartilage to near the margin of the fin, with their plane in the direction of the axis of the body: they alternate with the strata of muscular fibres, resembling the rays which support the fins of fishes.

The analogy of this structure to the cartilaginous basis of the great pectoral fin of the Ray is so close and satisfactory that we can scarcely hesitate to acknowledge the locomotive appendages of the mantle in the Decapodous Cephalopods as representatives of the pectoral fins of fishes, and consequently of the anterior extremity of the vertebrated animal. As they are not, however, fixed to a vertebral column, their situation is not constant, being sometimes, as in *Rossia*, situated towards the anterior part of the body; sometimes, as in *Loligo*, placed at the posterior extremity; just as we perceive the ventral fins of Fishes shifting their position, in consequence of a similar want of connexion, so as to occupy, in some species, a position more anterior even than the pectoral fins, without losing their essential character, as the analogues of the posterior extremities.

The cartilages of the fins correspond in length to the parts which they support, and are consequently much longer in the Cuttle-fish than in the Calamaries; in the Octopods they are entirely wanting.

Locomotive System.—The organs of locomotion in the Cephalopods are of two kinds, one consisting of appendages developed from the head; the other of rudimental fin-like extremities developed from the trunk; the latter organs are confined, as we have seen, to the Decapodous genera of the higher or Dibranchiate Order.

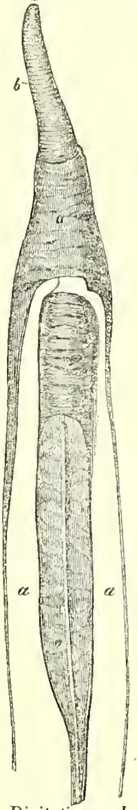
The cephalic processes, which are called digitations, arms, feet, tentacles, and peduncles, have no real homology with the locomotive extremities of the Vertebrata; to these they are analogous only, inasmuch as they

* Mémoires de l'Acad. Imp. des Sciences de tersbourgh, tom. ii. pt. 1 et 2, p. 154.

have a similar relation of subserviency to the locomotive and prehensile faculties of the animal.

Among the Vertebrates traces of organs corresponding to these cephalic feet are met with principally in the class of Fishes, in the form of tentacles developed from the lips; and Schultze, a learned German Naturalist,* has indicated the close affinity which the Cyclostomous Fishes bear, in this respect, to the Cephalopods; in one genus, viz. *Gastrobranchus*, or *Myxine*, eight free filaments are extended forwards from the circumference of the funnel-shaped orifice of the mouth, representing the eight ordinary arms of the *Cephalopoda Dibranchiata*, but arrested in their development because of the preponderating size of the caudal extremity of the body, which now forms the sole locomotive organ. The expanded sucker anterior to the jaws of the Lamprey may, in like manner, be considered to represent the united bases of the cephalic feet of the class under consideration.

Fig. 213.



Digitation and Tentacle, Nautilus Pompilius.

In the Nautilus the cephalic organs of prehension and locomotion consist of slender subcylindrical annulated tentacles, which are sheathed and retractile, (*fig.* 213,) like those of some of the Gasteropodous Mollusks, as *Doris*, *Thethys*, and *Tritonia*. Here, however, they astonish the observer by their unexampled number, surrounding the mouth in successive series, and amounting to little short of a hundred. These tentacles are divided into three kinds, according to their situation, viz. ‘ brachial or digital,’ ‘ ophthalmic,’ and ‘ labial:’ the latter being again subdivided into ‘ external’ and ‘ internal.’

The *brachial tentacles* are forty in number, and are supported by short conical trihedral hollow processes or digitations, (*e, e, fig.* 205,) of which the two superior or dorsal ones are conjoined and dilated into a muscular disk covering the whole upper part of the head, (*f, g, fig.* 205;) the remaining thirty-eight are disposed irregularly, nineteen on either side, one overlapping another, and all directed forwards, converging towards the orifice of the oral cavity, in which the jaws and mouth are concealed. The longest of these digitations, when its free extremity only is measured, does not equal one inch; but externally they appear longer, because they adhere for some way to the sides of the head. The digitations present no trace of acetabula or suckers, but are perforated at the extremity by a canal (*a, a, fig.* 213,) which is continued far into the substance of the head to near the cerebral ring; the tentacle (*b*) which is lodged in this canal, is consequently longer than the digitation from which it is protruded.

The *labial tentacles*, forty-eight in number, extend from orifices situated on the anterior margins of four broad flattened processes, arising from the inner surface of the oral sheath opposite the base of the mandibles. Two of these processes (*a, a, fig.* 219) are superior, posterior, and external in situation; the other two, (*b, b, fig.* 219,) which are smaller, are inferior, anterior, and more immediately embrace the jaws, and they are connected together by a lamellated organ (*c, fig.* 219), afterwards to be described. Each of these ‘labial’ processes is pierced by twelve canals containing the tentacles in question: they differ from the digital tentacles only in relative size, and in being of a softer and more delicate texture.

The *ophthalmic tentacles* seem more expressly designed as instruments of sensation; they do not possess the strength requisite for prehensile purposes, and are not situated conveniently for locomotive actions; they are four in number, and project laterally one before and one behind each eye, involuntarily reminding the observer of the antennæ in *Crustacea*, &c. At first sight they seem annulated like the brachial and labial tentacles; but upon a closer examination, they are found to consist of a number of flattened circular disks closely packed upon a lateral stem, a structure which is singularly analogous to that of the antennæ of the Lamellicorn Beetles. In this respect, however, the Pearly Nautilus does not stand alone in the Molluscous series, the retractile tentacula of the *Doris* present a very similar structure.

The fibres of the dense musculo-ligamentous sheath (*d, d, fig.* 219), which incloses the mandibles and supports the eyes and digital processes, arise from the whole of the anterior and outer part of the cartilaginous skeleton above described. They were so densely interwoven in the specimen we dissected as to preclude the possibility of ascertaining their exact course or arrangement.

The large lateral muscles of the funnel come off principally from the infundibular processes of the internal cartilage. There are also two small round and distinct muscles designed to draw the funnel closer to the head, they pass to their insertion through canals excavated in the sides of the funnel.

The fleshy masses which proceed backwards from the posterior part of the skeleton are the two great muscles (*b, b, fig.* 231,) which attach the Nautilus to its shell. These are inserted by obliquely truncated flattened extremities into a layer of horny substance which is closely adherent to the inner surface of the sides of the last chamber of the shell at a little distance from the septum forming its base where, in recent specimens, these impression are always to be plainly seen. The part which passes through the perforations of the septa is not a muscular or tendinous chord, as has been conjectured, but a weak membranous tub

* Meckel Archiv. für Physiologie, B. iv. p. 338. 1818.

which can lend but a feeble assistance in maintaining the shell in its natural position.

The mantle of the Nautilus is very thin and membranous, excepting at its free margin, where it is provided with longitudinal muscular fibres for its retraction, and a thin external stratum of transverse fibres, for the closing of its anterior aperture, during the expulsion of the respiratory currents.

The large mandibles (*a*, *b*, *fig.* 217; *e*, *f*, *fig.* 219,) are supported upon a fleshy substance (*g*, *fig.* 217), and moved by appropriate muscles. The fringed lip (*c*, *fig.* 217) which surrounds them is provided with a longitudinal stratum of fibres for its retraction, and an exterior orbicular sphincter at its anterior margin. The whole buccal apparatus is attached to the cartilaginous skeleton by four strong retractor muscles, two above (*h*, *h*, *fig.* 217, 219), and two below (*i*, *i*, *fig.* 217), and its base is surrounded by a transverse stratum of muscular fibres (*i*, *fig.* 219) continued from the external labial processes, across the upper or dorsal aspect of the jaws, which, by the contraction of these fibres, are protruded outwards.

The tongue (*fig.* 236) is a large complex muscular organ, the extremity of which is retracted by two pair of long slender muscles (*d*) arising from the dense membrane closing the lower part of the mouth; a third pair of muscles (*b*) given off from the posterior margins of the lower mandible are inserted into the anterior extremity of the horny lingual rasp hereafter to be described. Other internal muscular parts will be mentioned in the description of the viscera to which they relate.

The muscular system of the Dibranchiate Cephalopods, like their internal skeleton, is much more elaborately developed than in the inferior order of which the Nautilus is the type: but the same plan may be observed to govern the disposition of all the principal masses.

A hollow cone of muscular fibres is attached by a truncated apex to the anterior margin of the cephalic cartilage, or to processes developed therefrom, in order to afford these fibres an increased surface of origin. The fibres are interlaced, one with another, in a close and compact manner as the cone expands to form the cavity containing the fleshy mass of mouth; and at the anterior extremity of the mouth they are continued forwards and separate into eight distinct portions, which form the arms.

These organs are developed in a kind of inverse proportion to the body, being generally, as Aristotle* twice takes occasion to observe, longest in the short round-bodied *Octopi* or Poulps, and shortest in the long-bodied Calamaries, Sepiæ, &c. in which the two elongated retractile tentacles (*d*, *fig.* 207, 208, 209) are superadded, by way of compensation. These latter organs are rarely continued from the muscular cone inclosing the apparatus of the mouth, but arise from the cephalic cartilage, close together, internal to the origins of the ventral pair of brachia; they proceed at first outwards to a large membranous cavity situated anterior to the eyes, and thence emerge between the third and fourth arms on either side.

The acetabula or suckers are disposed along the whole extent of the inner surface of the ordinary arms, but are generally confined to the extremities of the tentacles, where they are closely aggregated on the inner aspect.

Of the difference between the arms and tentacles Aristotle was well aware, and accordingly, with his usual exactness, he applies to them distinct epithets: Πόδας μὲν οὖν ὀκτὼ ἔχει καὶ τούτους δικοτύλους πάντα πλὴν ἑνὸς γένος πολυπόδων. Ἴδια δ' ἔχουσιν αἵ τε σηπίαι καὶ αἱ τευθίδες καὶ οἱ τεῦθοι δύο προβοσκίδας μακρὰς ἐπ' ἄκρων τραχύτητα ἐχούσας δικότυλον.* "All (mollia) have eight *feet*, provided with a double series of suckers, except in one genus of Polypi.† The Sepiæ, Teuthides, and Teuthi,‡ have, besides, two long *proboscides*, the extremities of which are beset with a double series of suckers." Pliny gives, after the Stagyrite, the following notice of their functions, "Sepiæ et Loligini pedes duo ex his longissimi et asperi, quibus ad ora admovent cibos, et in fluctibus se, velut ancoris, stabiliunt." German authors generally term the ordinary feet, 'arms,' (*arme*,) and the tentacles 'seizers,' (*fangarme*.)

In the Cephalopods which have only the eight normal feet, these present many variations; and, although they are generally remarkable for their length, yet in some species, as the *Octopus brevipes*, they are extremely short, resembling the digital processes of the Nautilus. In *Octopus Eylais*, the first or dorsal pair is alone developed so as to serve as a locomotive organ, and the animal must crawl along the ground by means of this pair only.

In most Octopods the first pair of feet is the longest. In *Octopus Aranea*, in which the feet apparently present the maximum of development, the dorsal feet are ten times, and the ventral ones five times, the length of the body. Besides their superior length the dorsal feet present other peculiarities in this family of Cephalopods. In the genus *Argonauta* (*fig.* 206, *c* 1,) they are provided with expanded membranes, the fabled use of which has afforded a beautiful subject for poetic imagery in all ages; but similar appendages occur in *Octopus violaceus*, and in *Octopus velifer*, in which both the first and second pairs of feet support broad and thin membranes at their extremities. Now neither of these species inhabit a shell, in which the expanded membranes could be used to waft the animal along the surface of the ocean, as has been said or sung of the Argonaut from Aristotle to Cuvier, from Callimachus to Byron. The physiologist, in contemplating the structure of the velated arms, is compelled to disallow them the power of being maintained erect and expanded to

* De Historia Animalium, (Ed. Schneider, Lipsiæ,) lib. iv. c. 1. 8 & 9.

* Ibid. lib. iv. c. 1. 4.

† The genus *Eledone* of Aristotle, the eight feet of which have only a single series of suckers upon each.

‡ Species of *Loligo* or Calamaries, supposed to be the *Loligo vulgaris* and *Loligo media* of modern naturalists.

meet the breeze. What their real function may be is still to be determined; but the removal of the erroneous impressions entertained on this subject is the first step towards the attainment of the truth.

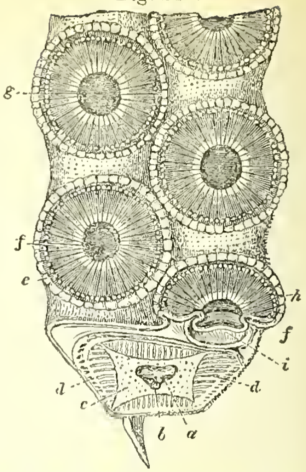
In our common *Octopus*, and most other species of this genus, the feet are connected together for some distance beyond the oral sheath by membranes and muscles which form a circular fin. This is their sole locomotive organ when swimming; and by its powerful contraction they are driven through the water with a quick retrograde motion. In a species which we have recently described* (*Octopus semipalmatus*) the fin is extended only between the four dorsal arms: a structure which must occasion a characteristic difference in its mode of swimming.

The disposition of the muscles of the web-like fin is as follows. There are two transverse layers of fibres, the external arises from a white line extending along the back-part of each foot; the internal from the sides of the same feet between the attachments of the suckers. These two strong muscular bands are connected together as they pass from arm to arm in the middle of the webs, and decussate one another, so that the external become internal and *vice versa*. Within these a thin layer of longitudinal fibres extends to the free margin of the webs; and there is also a layer of oblique longitudinal fibres externally, which arise from the white line at the middle of each foot: these fibres are shown at (*k*, *k*, *fig.* 216,) the transverse fibres at *l*, *l*.

In the Cephalopods which possess the retractile peduncles, the ordinary arms are generally short, and the first or dorsal pair are commonly exceeded in length by the second; sometimes, indeed, as in the species of *Loligopsis*, of which the figure is subjoined, (*fig.* 209,) they go on progressively increasing in length to the ventral or fourth pair, which here resembles in its great development the arms of the Octopods. The peduncles are always longer, and more slender than the arms; they exhibit these characters in the highest degree in the genus *Loligopsis*, in which they are frequently mutilated and lost; but the examination of the nerve proceeding to the mutilated stump sufficiently attests, in such cases, the importance of the organ of which this animal has been accidentally deprived. The tentacles serve to seize a prey which may be beyond the reach of the ordinary feet, and also to act as anchors to moor the Cephalopod in safety during the agitations of a stormy sea.

Each arm is perforated near the centre of its axis for the lodgment of its nerve (*a*, *fig.* 214) and artery (*b*); and upon making a transverse section of the arm, these are seen to be lodged in a quadrangular or rhomboidal space (*c*) of a light colour and apparently soft homogeneous texture, but in which a few radiating fibres may be discerned. This part is surrounded by four

Fig. 214.



Section of an Arm and Suckers of a Poulp.

groups of transverse striæ forming as many segments of a circle, external to which there are two thin circular strata of fibres. On making a longitudinal section of the part the striated segments are seen to consist of longitudinal muscular fibres, and of the surrounding strata, the fibres of the internal are longitudinal, and those of the external transverse. It is easy to conceive that, like the tongue in Mammalia, the arms thus organized may be lengthened, shortened, curved, and bent in all conceivable directions.

The acetabula or suckers with which the internal surface of the arms of the Dibranchiates are provided, vary in relative position, in size, in structure, and in mode of attachment, not only in different species, but in different arms in the same individual, and sometimes in different parts of the same arm. Thus in the peduncles of *Loligopsis Veranii*, the suckers on the long cylindrical stem are sessile, while those on the expanded extremity are supported on long peduncles; and another remarkable instance will presently be mentioned of suckers having different structures for different functions in the same arm.

In the Dibranchiate genera which are characterized by a soft thin skin, as the Argonaut, Octopus, and Eledone, the suckers are soft and unarmed; in those genera which have a hard and thick skin, as the Calamary and Onychoteuthis, cuticular appendages are developed in the cavities of the suckers.

An excellent description of the unarmed acetabulum as it exists in the genus *Octopus*, is given by Dr. Roget.

The circumference of the disc is raised by a soft and tumid margin (*e*, *fig.* 214); a series of long slender folds of membrane (*f*), covering corresponding fasciculi of muscular fibres, converge from the circumference towards the centre of the sucker, at a short distance from which they leave a circular aperture (*g*): this opens into a cavity (*h*), which widens as it descends, and contains a cone of soft substance

* See Proceedings of the Zoological Society for March, 1836.

(*i*) rising from the bottom of the cavity, like the piston of a syringe. When the sucker is applied to a surface for the purpose of adhesion, the piston, having previously been raised, so as to fill the cavity, is retracted, and a vacuum produced, which may be still further increased by the retraction of the plicated central portion of the disc. So perfect is the mechanism for effecting this mode of adhesion, that in the living Cephalopod, "while the muscular fibres continue contracted, it is easier to tear away the substance of the limb than to release it from its attachments: and even in the dead animal the suckers retain a considerable power of adhesion."*

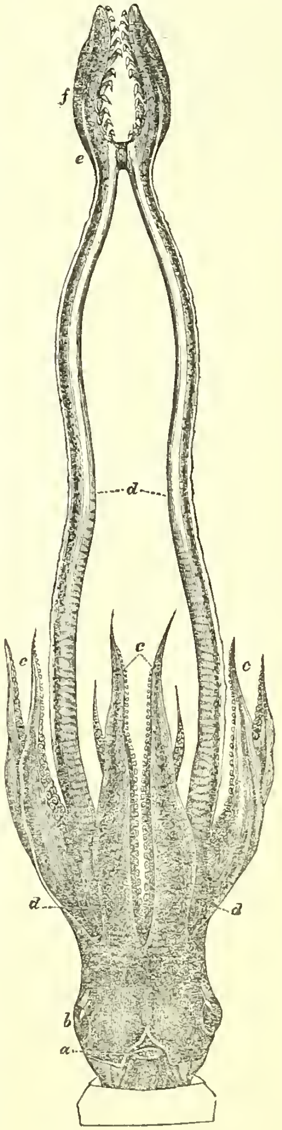
Still there are circumstances in which even this remarkable apparatus would be insufficient to enable the Cephalopod to fulfil all the offices in the economy of nature for which it was created; and in those species which have to contend with the agile, slippery, and mucus-clad fishes, more powerful organs of prehension are superadded to the suckers.

In the Calamary the base of the piston is inclosed by a horny hoop, the outer and anterior margin of which is developed into a series of sharp-pointed curved teeth. These can be firmly pressed into the flesh of a struggling prey by the contraction of the surrounding transverse fibres; and can be withdrawn by the action of the retractor fibres of the piston. Let the reader picture to himself the projecting margin of the horny hoop developed into a long, curved, sharp-pointed claw, and these weapons clustered at the expanded terminations of the tentacles, and arranged in a double alternate series along the whole internal surface of the eight muscular feet, and he will have some idea of the formidable nature of the carnivorous Onychoteuthis.

Banks and Solander, in Cook's first voyage, found the dead carcase of a gigantic species of this kind floating in the sea, between Cape Horn and the Polynesian Islands, in latitude 30° 44′ S. longitude 110° 33′ W. It was surrounded by aquatic birds, which were feeding on its remains. From the parts of this specimen, which are still preserved in the Hunterian Collection, and which have always strongly excited the attention of naturalists, it must have measured at least six feet from the end of the tail to the end of the tentacles. The natives of the Polynesian Islands, who dive for shell-fish, have a well-founded dread and abhorrence of these formidable Cephalopods, and one cannot feel surprised that their fears should have perhaps exaggerated their dimensions and destructive attributes.

We cannot quit this part of our subject without noticing a structure which adds greatly to the prehensile powers of the uncinated Calamaries: at the extremities of the long tentacles, besides the uncinated acetabula, a cluster of small simple unarmed suckers may be observed at the base of the expanded part. When these latter suckers are applied to one another, the tentacles are firmly locked together at that part, and the united strength of both the elongated peduncles can be applied to drag towards the mouth any resisting object which has been grappled by the terminal hooks. There is no mechanical contrivance which surpasses this structure: art has remotely imitated it in the fabrication of the obstetrical forceps, in which either blade can be used separately, or, by the interlocking of a temporary joint, be made to act in combination. (See *fig.* 215, where *d* marks the stems of the peduncles, *e* the parts joined together by the mutual apposition of the unarmed suckers, *f* the terminal expanded portions bearing the hooks.)

Fig. 215.



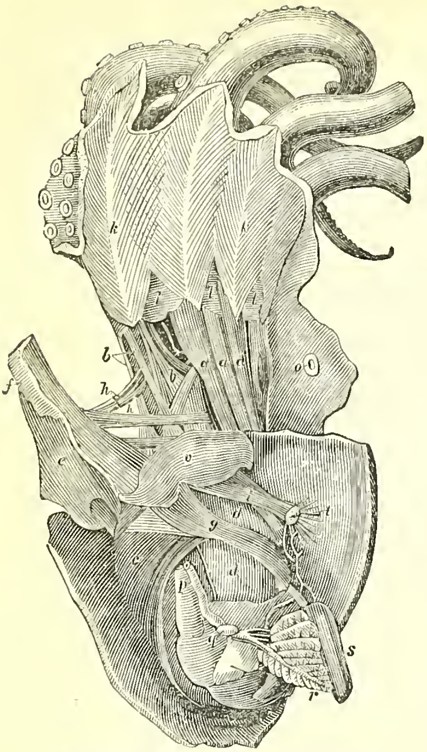
Arms and Tentacles of an Onychoteuthis.

The great muscular conical basis which gives origin to the feet is attached, as before mentioned, to the anterior part of the annular cephalic cartilage: it is also provided with distinct fasciculi of muscular fibres, which connect it to the mantle and to other parts of the body.

In the *Octopus* a great proportion of these fibres arise from the posterior part of the mantle, and, diverging as they pass forwards, spread over the posterior and lateral parts of the head, receding at the sides to leave a space for the eye; they then divide into five bundles, each of which again subdivides into two, which are lastly inserted into the sides of the six dorsal and lateral feet. (See *a, a, fig.* 216.)

* Roget, Bridgewater Treatise, i. p. 260. See also Baker, An Account of the Sea-Polypus, Philosoph. Trans. vol. l. p. 777.

Fig. 216.



Muscles of the Poulp, Octopus Vulgaris.

Fasciculi of muscular fibres (*b, b,* 216,) are continued from the ventral pair of feet and the back part of the cranium, across the base of the funnel to the muscular septum, which divides longitudinally the branchial cavity. Other fibres descend to join the muscular tunic enveloping the liver and œsophagus (*d, d*); but the fibres of this part rise principally from the posterior part of the cephalic cartilage.

The septum of the branchial chamber above-mentioned is the strongest and most complete in the genus *Eledone*, where, with the exception of a very small part of its posterior termination, it is muscular throughout.* In the Poulp, in which this septum (*c, fig.* 216) is well described by Cuvier as the "bride anterieure qui lie la bourse à la masse viscerale," a greater proportion of the posterior part is membranous. In the *Argonauta* the muscular part of the septum is reduced to two narrow and delicate fasciculi, which arise from the back part of the cranial cartilage, descend obliquely forwards, intercept the termination of the rectum and ink-duct, to which they serve as a sphincter, and then expand in the vertical direction to be inserted along the middle line of the inner surface of the anterior part of the mantle. A membrane is continued from the upper margin of the muscular septum to within a short distance of the anterior margin of the mantle, and another from the lower margin extends downwards, and terminates opposite the base of the gills; the branchial chambers intercommunicate both above and below this septum. In *Sepiola* the muscles corresponding to the "*bride anterieure*" of the *Octopus* are developed in the same degree as in the Argonaut, arising not from the back of the funnel, but from the cranial cartilage; the septum is completed below by membrane. In the Cuttle-fishes and Calamaries these muscles and the septum of the branchial chamber are wanting.

The muscular parietes of the funnel are formed by an external longitudinal (*e*) and an internal transverse (*f*) layer, strengthened by the insertion of the extrinsic muscles of this part. The principal of these are the lateral muscles (*g, fig.* 216,) which in the Poulp take their origin from the capsules of two small styles, hereafter to be described, at the sides of the mantle, and are inserted into the sides of the funnel and the muscular tunic of the liver. In the Cuttle-fishes and Calamaries they are attached to the cartilaginous articular cavity at the sides of the base of the funnel, as well as to its fleshy parietes.

These muscles serve to retract and depress the funnel; it is raised and drawn forwards by two pair of muscles (*h*) which descend from the under and lateral parts of the head to be inserted into its back part. But neither of these muscles pass through a sheath, as do the corresponding muscles in the Nautilus.

A pair of muscles, whose important character is only perceived by tracing them through their successive stages of development to the Nautilus, are those small fasciculi which Cuvier terms "la bride laterale qui joint la bourse à la masse viscerale." (*i.*) They arise in conjunction with the fibres of the fleshy tunic of the liver, but soon quitting these, extend, as distinct fasciculi, downwards and outwards, being perforated in their course by the great lateral nerve, and are inserted into the upper part of the capsule of the rudimental shell, which the styles above-mentioned represent. In the *Sepia* they are proportionally larger, corresponding to the greater development of the shell. They are not inserted, in the *Octopus*, into the cartilaginous substance of the inclosed style; nor, in the *Sepia*, into the calcareous substance of the cuttle-bone; neither are they attached to the calcareous matter of the shell in the *Nautilus*, where they acquire their maximum of development. They terminate in this, as in the preceding genera, in the epidermic capsule of the shell, which has a much closer and more intimate adhesion to the testaceous substance in the Nautilus than to the internal rudiment of the same part in the naked Cephalopods.

It is well known that zoologists are divided in opinion as to whether the shell called *Argonauta* is formed by the cephalopod which inhabits it or not. Having traced out the muscles in the naked Cephalopods which are analogous to those of the shell in the *Nautilus*, we next examined the *Ocythoë*, with the view of

* See Carus' original figure, Vergleich. Zootomie, pl. iv. fig. 4, g. in *Octopus (Eledona) Moschatus.*

ascertaining if these muscles presented a corresponding degree of development, but found them proportionally smaller even than in the naked *Octopus*. All trace of internal shell has disappeared in the *Ocythoë*; yet there is no muscular connexion between the body and the external shell which contains it.

The fleshy fibres of the mantle being white like the rest of the muscles, and very compact, are extremely difficult to follow in dissection. Cuvier* observes, that in the *Octopus* those which are external are evidently longitudinal; those which are internal, transverse; and that there are short fibres which pass through their thickness from one surface to another.

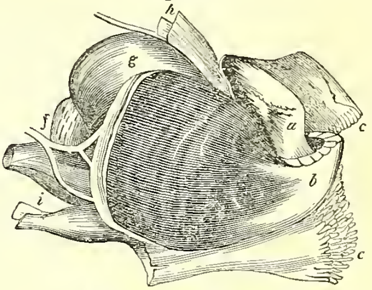
In the Cuttle-fish the muscular fibres of the posterior part of the mantle recede laterally to leave a large space for the lodgement of the *sepium* or cuttle-bone, which is covered externally by a thin and flaccid skin: the rest of the mantle is formed by a thick muscular tissue, as in the *Poulp*. The lateral fins are connected not only by the skin, cellular tissue, and vessels, as Cuvier describes, but by a distinct though thin stratum of muscular fibres; these arise from the lateral and dorsal aspects of the aponeurotic capsule of the rudimental shell, and are inserted into the spinal ridge of the alar cartilage (*h, h, fig.* 212); from this ridge proceed the fibro-cartilaginous laminæ and intermediate muscles, which are disposed perpendicularly to the ridge, and extend to the margins of the fin.

In the Calamaries the muscles which connect the terminal fins to the body are still more distinct. By means of these fins they are enabled to propel themselves forward in the sea; and there is good reason for believing that some of the small slender-bodied subulate species of this genus are enabled to strike the water with such force as to raise themselves above the surface, and dart, like the flying fish, for a short distance through the air.†

Digestive System.—The animals which we have thus seen to be endowed with so various and formidable means for seizing and overcoming the struggles of a living prey are provided with adequate weapons for completing its destruction, and preparing it for deglutition. These consist of a pair of strong, sharp, hooked mandibles, which are of a horny texture in the Dibranchiate Cephalopod, (*a, b, fig.* 218,) where they are fitted for cutting and tearing the softer animals which they are enabled to catch; but are strengthened by a dense calcareous substance in the Nautilus, (*a, b, fig.* 217,) which, from its more limited sphere of action, is probably restricted in regard to food to such crustaceous and testaceous animals as it may surprise by stealth, and whose defensive armour it is thus enabled to break up.*

The mandibles, which are hollow sheaths, like the horny covering of the beak of a Bird or Tortoise, are fixed upon a firm fleshy substance, (*c, c, fig.* 217,) which resembles the

Fig. 217.



Mandibles of the Nautilus.

animal part of bone after the earth has been removed by means of an acid. At the base of the mandibles the fibrous structure of this part becomes apparent, and a strong stratum, (*g, fig.* 217,) passing between the bases of the mandibles, serves for their divarication; their closure is effected by fasciculi of muscular fibres, which surround them externally near the reflection of the circular lip. When the mouth is closed, the lower mandible (*b*) overlaps the upper (*a*).

The oral aperture is in the centre of the base of the feet, and appears in the form of a small circular orifice, formed by the contracted fleshy lip which surrounds and more or less conceals the mandibles.

In the Nautilus the margin of the lip (*c*) is beset with several rows of elongated papillæ, irregularly disposed; external to which are the labial processes with their tentacles: these, in the specimen we dissected, completely overlapped and concealed the oral apparatus.

In the Calamaries the jaws are surrounded, external to the fringed circular lip, by a thin membrane, which is produced into short pyramidal processes, corresponding in number to the eight feet, and supporting minute rudimental suckers; thus imitating the external feet, as the labial processes of the Nautilus repeat the structure of the digital processes. In the genus *Sepioteuthis* the circular lip immediately surrounding the jaws is tumid and plicated, but not papillose; external to it are two circular ridges of membrane, then a thin membrane with jagged margins, and lastly a membrane with its margin produced into eight angular processes, which are not, however, free, as in *Loligo*, but are tied down in the interspaces of the eight legs; small rudimental suckers may be observed on these processes.

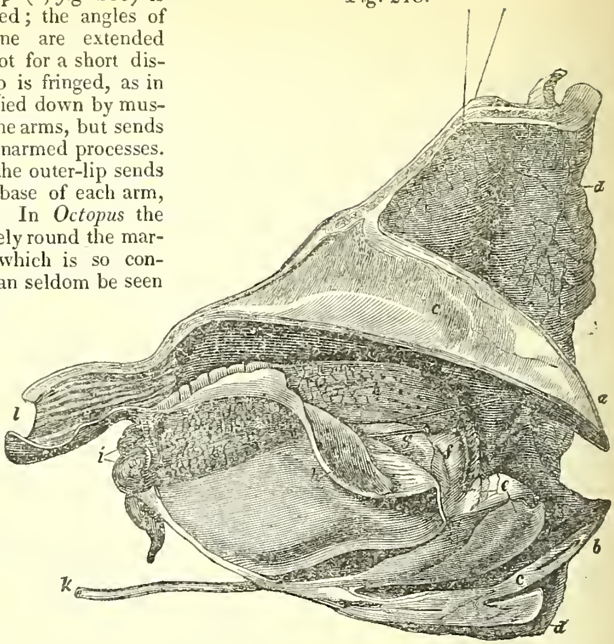
* Mémoire sur le Poulpe, p. 11.

† See Proceedings of the Zool. Society, Pt. i, 1833, p. 90. The faculty possessed by the Calamaries of darting through the atmosphere was not unknown to the ancients. Pliny (*Hist. Nat.* lib. ix. tom. ii. p. 105, Cuvier's Ed.) says, "Loligo etiam volitat, extra aquam se efferens, quod et pectunculi faciunt sagittæ modo;" and so general appears to have been this belief that Varro supposed the name *Loligo* to be a corruption of *Voligo*. "Loligo dicta, quod subvolat, littera commutata, primo *Voligo*."—*De Ling. Lat.* lib. iv. p. 21.

* The digestive canal of the Nautilus was found filled exclusively with the remains of a species of crab.

In *Onychoteuthis* the inner lip (*d*, *fig.* 218) is tumid, and merely subplicated; the angles of the external labial membrane are extended along the middle of each foot for a short distance. In *Sepia* the inner lip is fringed, as in *Nautilus*. The outer lip is tied down by muscular bands to the bases of the arms, but sends forward eight short, conical, unarmed processes. In *Loligopsis* and *Cranchia* the outer-lip sends off a muscular band to the base of each arm, but has no free processes. In *Octopus* the suckers commence immediately round the margin of the oral aperture, which is so contracted that the mandibles can seldom be seen without dissection: the inner-lip is fimbriated, as in *Sepia*. In *Ocythoë* it is tumid and entire, but plicated both circularly and transversely.

Fig. 218.



Section of the Beak, with the Tongue of an Onychoteuthis.

The *tongue* is a large and complicated organ, and is constructed on the same plan in both orders of Cephalopods. In the Nautilus it is supported by an oblong horny transversely striated substance, which appears to represent the body of an os hyoides (*a*, *fig.* 236.) The posterior extremity of this substance is free, or connected only by a few filaments with the parts above, but its anterior extremity is embraced by a pair of retractor muscles (*b*), which originate from the posterior margins of the lower mandible. The fleshy substance of the tongue, thus supported, is produced anteriorly, and forms three caruncles (*c*), very soft in texture, and beset with numerous papillæ, having all the characters of a perfect organ of taste. The anterior or terminal caruncle is the largest, and four delicate retractor or depressor muscles (*d*) are inserted into it. Behind the caruncles the dorsum of the tongue is encased with a thin layer of horny matter, about five lines in length, from which arise four longitudinal rows of slender prickles (*e*), which are from one to two lines in length, and are incurvated backwards. The number of these prickles is twelve in each row, singularly corresponding with the number of tentacles given off from the labial processes.

It is unnecessary to allude to the obvious utility of this structure in seizing the morsels of food, and directing them towards the gullet, after they have been broken up by the mandibles. Behind this horny part the tongue again becomes soft and papillose (*f*), but the papillæ are coarser and larger than those on the anterior portions. Two broad fleshy processes (*g*, *g*,) project forwards from the sides of the fauces: these also are papillose, and are perforated in the middle of their inner surfaces by a small aperture (*h*, *h*), which leads into a glandular cavity, situated between the folds of the membrane, and analogous to the superior pair of salivary glands in the Poulp, Calamaries, &c.

In the Dibranchiate Cephalopods the tongue is similarly composed of an anterior and posterior papillose and a middle spiny portion. In the specimen from which the figure (218) was taken, the anterior fleshy portion (*e*) was slightly divided into three parts, but was retracted by a single round muscle, and the papillæ were relatively fewer and coarser than in the Nautilus: at its sides there were several orifices of glandular follicles. The horny plate, covering the middle part of the tongue, is bent at right angles; the recurved hooks in the Onychoteuthis are confined to the anterior and vertical surface; they commence above or behind in seven rows; but, as they descend, first the two outer on each side blend together, and then each united row joins the next, so that there remain but three rows at the lower part of the sheath. In the Cuttle-fish the seven rows of lingual spines continue distinct.

In the Onychoteuthis the posterior portion of the tongue (*g*) is inclosed, as in the Nautilus, between two faucial or pharyngeal folds of membrane (*h*, *h*), but their inner surfaces, instead of being merely papillose, are beset with rows of small recurved spines, which must greatly assist the act of deglutition.

The superior *salivary glands* (*i*) are not confined to the outside of the buccal mass, as in the *Octopus*, but extend between the layers of membrane which form the pharyngeal fold, forming here a flattened mass (*i*); their duct opens at the bottom of a longitudinal fissure on the inner surface of the fold; styles are represented passing into the ducts of these glands in the figure.

In most of the *Dibranchiata* a second and generally larger pair of salivary glands are found below the cartilaginous cranium, situated in the hepatic cavity, on either side of the œsophagus. A single excretory duct is continued from each gland, and the two unite and form one, as they are passing through the cranium. The common duct penetrates the lower or central surface of the buccal mass, and is continued along the concavity of the lower mandible, through the tongue to the lower part of the spiny plate, where it terminates. In the *Octopus* these glands are very large, and have a smooth surface (*q*, *fig.* 233); but in many Cephalopods, as in *Ocythoë*, *Sepiola*, and *Rossia*, they are relatively smaller, and have a granular surface. It is in the genus *Loligopsis* alone that these glands have hitherto been found wanting.

With respect to the ultimate structure of the salivary glands of the *Cephalopoda*, Müller* observes that they are not composed of solid acini or granules, but of hollow canals or cells.

Before the description of the abdominal viscera is proceeded with, it is necessary to make a few observations on their position and connections.

In the ventricose and short-bodied species of *Cephalopoda* the mantle-sac is almost wholly filled with the viscera, but in those of an elongated form they are more or less confined to the lower part of the sac, and a vacant space intervenes between the visceral mass and the opening of the mantle, which is traversed by the respiratory currents: the part of the mantle unoccupied by the viscera is most remarkable for its extent in the genus *Loligopsis* (*fig.* 223.)

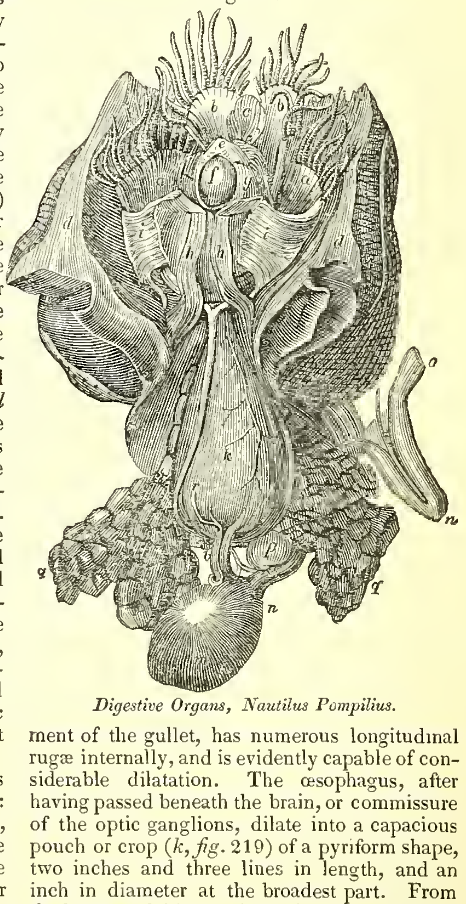
If the mantle of the common Octopus or Poulp be laid open longitudinally, and a little to one side of the mesial line, a cavity will be exposed, separated by the longitudinal muscular septum (*c*, *fig.* 216) from the corresponding one of the opposite side; in these two cavities are contained the branchiæ (*r*, *fig.* 216), the terminations of the oviducts (*p*), and the pericardial apertures (*q*). Below and behind the *branchial cavities*, the peritoneum is seen enveloping the rest of the viscera; but this great serous sac is subdivided into many compartments. If the point of the scissors be inserted into the projecting orifice internal to the root of the gill (*i*, *fig.* 226), and the cavity of which it is the outlet be laid open, the branchial ventricle, the branchial division of the vena cava, and its appended follicles will be exposed; this cavity is separated from a corresponding one on the opposite side by the systemic heart and the great vessels, which are contained in a distinct serous compartment. In the Nautilus the two lateral and the middle cavities form one large *pericardiac* chamber, appropriated to the heart and great vessels, and the venous appendages.

Behind these cavities, the peritoneum is disposed so as to form several compartments: one, which commences at the cranial cartilage, extends downwards as far as the middle of the branchiæ, and contains the œsophagus, the inferior salivary glands, the crop, and anterior aorta: in front of this, but commencing a little lower down, is a second, which includes the liver and ink-bag. These two cavities are surrounded by a common muscular tunic, of which we have already spoken, and the lower part, which resembles a diaphragm, is perforated by the gullet, the aorta, and the two biliary ducts, each of which has a distinct aperture. The receptacle which contains the gizzard is situated immediately beneath the œsophageal sac; that in which the spiral pyloric appendage is lodged lies immediately behind the left compartment of the pericardium. The intestine is principally contained in a serous cavity behind the right division of the pericardium; and the bottom of the sac is occupied by the cavity containing the organs of generation.

The digestive organs in the Tetrabranchiate Cephalopods would appear to differ in a less degree than other parts of their organization from the structures observable in the higher order: in the Nautilus they present the following conformation.

The pharynx (*f*, *fig.* 217) or commencement of the gullet, has numerous longitudinal rugæ internally, and is evidently capable of considerable dilatation. The œsophagus, after having passed beneath the brain, or commissure of the optic ganglions, dilate into a capacious pouch or crop (*k*, *fig.* 219) of a pyriform shape, two inches and three lines in length, and an inch in diameter at the broadest part. From the bottom of this crop is continued a contracted canal (*l*, *fig.* 219,) of about three lines in diameter, and half an inch in length, which enters the

Fig. 219.



Digestive Organs, Nautilus Pompilius.

* De structurâ glandularum penitiori, fol. p. 54.

upper part of an oval gizzard (*m*, *fig.* 219) situated at the bottom of the pallial sac. Close to where this tube enters, the intestine (*n*, *fig.* 219) is continued from the gizzard, and after a course of a few lines communicates with a small round laminated pouch or appendage (*p*, *fig.* 219) analogous to the spiral cœcum of the Cuttlefish, into which the biliary secretion is poured: from thence the intestine is continued, twice bent upon itself, but without varying materially in its dimensions, to its termination (*o*, *fig.* 219). In this course it first ascends for about an inch and a half, then makes a sudden bend down to the bottom of the sac, and returns as suddenly upon itself, passing close to the pericardium, and terminating between the roots of the branchiæ.

The alimentary canal is every where connected to the parietes of the abdomen by numerous filaments; the only trace of a mesentery exists between the two last portions of the intestine, which are connected together by membranes including the ramifications of an artery and vein.*

The longitudinal rugæ, into which the lining membrane of the œsophagus is thrown, disappear at its entrance into the crop. The muscular coat of the crop consists of an exterior layer of close-set circular fibres and an inner layer of more scattered longitudinal ones. The lining membrane is thin but tough, with a smooth surface: when the cavity is empty, it is probably thrown into longitudinal folds by the action of the circular fibres.

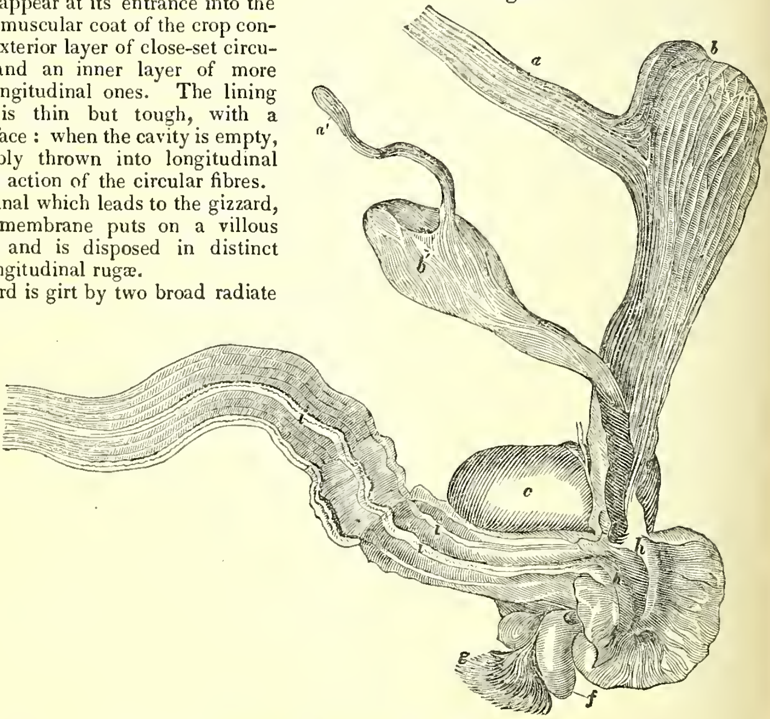
In the canal which leads to the gizzard, the lining membrane puts on a villous appearance and is disposed in distinct close-set longitudinal rugæ.

The gizzard is girt by two broad radiate muscles, of the thickness of two lines, arising from opposite tendons: it is lined by a thick cuticular membrane, delicately furrowed and adapted to numerous fine ridges which traverse longitudinally the whole interior of the cavity. This, as is commonly found in gizzards, was detached from part of the parietes and adhered very slightly to the remainder.

The pyloric orifice is close to the cardiac, and is guarded by a valve, to prevent a too ready egress of matter from the gizzard.*

The globular cavity (*p*, *fig.* 219) which communicates with the intestine at a little distance from the pylorus, is occupied with broad parallel laminæ, which are puckered transversely, so as to increase their surface for vascular ramifications; their texture under the lens is follicular and evidently fitted to secrete. The bile enters this cavity at the extremity furthest from the intestine by a duct large enough to admit a common probe. The two laminæ on each side the entrance of the duct increase in breadth as they approach the intestine, and are continued in a curved form

Fig. 220.



Alimentary Canal of the Poulp.†

* In the specimen of the Nautilus from which the preceding account is derived, the whole alimentary canal was filled with fragments of some species of crab, among which portions of branchiæ, claws, and *palpi*, were distinctly recognizable. The crop in particular was tensely filled with these substances, and the capability of propelling such rude and angular particles through a narrow canal in the gizzard, without injury to the thin tunics of the preparatory cavity, is a remarkable example of the superior powers of living over dead matter.

* The contents of this part of the alimentary canal were in smaller pieces than in the crop, but of the same nature; the fragments of shell were comminuted apparently by mutual attrition, as there were no particles of sand or pebbles present.

† From Férussac's Monograph on the *Céphalopodes Acetabulifères.*

along that canal, being gradually lost in its inner membrane, the lamina next the gizzard is peculiarly enlarged, so as evidently to present an obstacle to the regurgitation of bile towards the gizzard. The inner surface of the rest of the intestinal canal presents a few longitudinal rugæ, with slightly marked transverse puckerings.

In the Dibranchiate Cephalopods the gullet, in consequence of the position of the stomach near the lower part of the visceral sac, is of great length (*a*, *a*, *fig*. 221), but varies in this respect according to the form of the animal. We have seen that in the *Nautilus* it is dilated into a pyriform crop; a similar dilatation occurs in the genus *Octopus;* but its position is reversed, the larger end of the sac being uppermost, and probably as the result of the habitually reversed position of the animal with the head downwards, the crop is extended into a large cul-de-sac above the part where the œsophagus opens into it (*b*, *fig*. 220). From this part the crop gradually contracts to its termination.

In the Argonaut the crop commences by a similar lateral dilatation, but is continued of almost uniform breadth to the stomach.

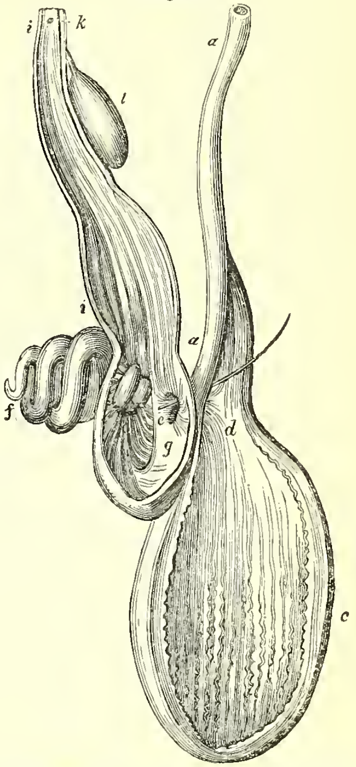
In the *Sepia*, *Sepiola*, *Rossia*, *Onychoteuthis*, *Loligopsis*, and *Loligo*, and probably in the other Decapods, there is no crop, the gullet being continued of uniform breadth to the stomach (*a*, *a*, *fig*. 221).*

The stomach (*c*, *figs*. 220, 221,) in all the Dibranchiate Cephalopods is a more or less elongated sac, having its two orifices, the cardia (*d*) and pylorus (*e*), close together at the anterior or upper part of the sac, as in the gizzard of birds: the muscular fibres are similarly disposed, and radiate from two opposite tendons; they form a stratum of about the same thickness as in the stomachs of omnivorous birds. The epithelium, which is continued from the œsophagus and crop (*a′*, *b′*, *fig*. 220) acquires a greater thickness in the gizzard, and is disposed in longitudinal rugæ; it is readily detached from the muscular tunic.

The intestine, at a short distance from the pylorus, communicates with a glandular and laminated sac, analogous to the pyloric appendages in Fish, but which in the Cephalopods is always single.

In the Nautilus, we have shewn that this rudimental pancreas (*p*, *fig*. 219) is of a simple globular form, as in the Doris and some other Gasteropoda. It presents a similar form in *Rossia* and *Loligopsis*, in the latter of which it is of large size (*g*, *fig*. 223). In *Argonauta* it is triangular; in some species of *Loligo*, as in the *Loligo communis*, it is extended into a long pyriform membranous bag, but in the *Loligo sagittata*, *Sèpia*, and *Octopus*, it is elongated and twisted spirally, whence it is compared by Aristotle to the shell of a Whelk (*f*, *figs*. 220, 221). In each of these

Fig. 221.



*Alimentary canal of the Sagittated Calamary.**

genera its cavity is occupied by glandular laminæ (*g*, *g*); the biliary ducts terminate between two of the largest folds, which make a curve as they pass into the intestine, and are continued, gradually diminishing in size, along the canal, presenting at its commencement two tumid projections, which tend to prevent a regurgitation of bile towards the pylorus.

The intestine in the *Nautilus* makes a loop, or narrow fold upon itself before it is continued forwards to the base of the funnel. In the *Octopus* it is characterized by a similar fold, but in the Cuttle-fish and Calamary the gut is continued in a straight line from the stomach to the vent (*i*, *i*, *fig*. 221), and is consequently very short and simple: in both cases it maintains nearly a uniform diameter to its termination.

The internal tunic of the intestine is disposed in longitudinal folds, of which the two at its commencement, above described (*i*, *i*, *fig*. 220), are the most conspicuous. The longitudinal rugæ in the *Sepioteuthis* and Cala-

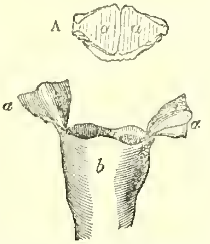
* From this difference I conclude that Aristotle took his description of the digestive viscera of the Malakia from the *Sepia* or *Teuthis:* he says, Μετὰ δὲ τὸ στόμα ἔχουσιν οἰσοφάγον μακρὸν καὶ στενόν, ἐχόμενον δὲ τούτου πρόλοβον μέγαν καὶ φεριφερῆ ὀρνιθώδη. "After the mouth they have a long and narrow œsophagus, then a large round gizzard similar to that of a bird."—*Hist. de Anim.* lib. iv. c. 1.9. But it is evident that he also had dissected the *Octopus*, as he afterwards notices the difference in the position of the ink-bag, which occurs in this genus as compared with the Sepia.

* Home, Lecturos on Comp. Anat. pl. lxxxiii.

mary terminate abruptly where the duct of the ink-bag enters the gut (*k*, *fig*. 221), which for the small extent beyond this part is smooth internally.

In the Octopods the intestine passes through the muscular septum of the branchial chamber, immediately above which it terminates. In the Decapods the rectum and duct of the ink-gland are surrounded by the muscular fibres which connect the pillars of the funnel to one another; in both cases the fibres serve as a sphincter to the anus.

Fig. 222.



Anal valves, Sepioteuthis.

In many *Dibranchiata*, especially the Decapods, the termination of the rectum is provided with two lateral fleshy appendages; for which, as far as we know, no use has hitherto been assigned. In the Sepioteuthis these processes (*a*, *a*, *fig*. 222) are of a broad inequilateral triangular form, attached to the sides of the transverse anal aperture (*b*) by their acute angle, from which a ridge extended longitudinally to the middle of the base; when the processes were folded down upon the vent (as in *A*, *fig*. 222), the ridge fitted into the aperture, so as accurately to close it. In the Cuttle-fish the corresponding processes are of a rhomboidal form, with a thicker ridge on the side next the anal aperture, which they in like manner are adapted to defend against the entrance of foreign substances by the funnel. In other genera they are not adapted to defend the anus mechanically, being elongated and filiform; but they probably serve to give warning of the presence of foreign bodies, and excite the necessary contraction of the constrictors of the gut; Rathké compares them to antennæ in the *Loligopsis*, where the anal processes are very long (11, *fig*. 223).

The apparatus for secreting the inky fluid, formerly regarded as characteristic of the class of Cephalopods, is wanting in the Nautilus, which, as it has a large and strong shell to protect its body, stands less in need of such a means of defence: the ink-bag is, however, present in the Argonauta.

The ink-bag (*l*, *fig*. 221) varies in its relative position in different *Dibranchiata:* in the Cuttle-fish it is situated near the bottom of the pallial sac, in front of the testicle or ovary. In the Calamary it is raised close to the termination of the intestine; we have found it similarly situated in the Argonauta, Sepioteuthis, and Rossia. In the Octopus it is buried in the substance of the liver, a small part only of its parietes appearing on the anterior surface of that gland, from which its duct is continued forwards to terminate in this genus immediately behind the anus.

From this connection of the ink-bag with the liver in the Poulp, Monro was led to suspect it to be the gall-bladder. What its real nature may be still remains doubtful; De Blainville and Jacobson regard it as a rudimental urinary apparatus:* Sir Everard Home † compares it to the secreting sac which opens into the rectum in Rays and Sharks, and this we consider to be the true homology of the ink-bag. It is interesting, indeed, to observe that corresponding anal glandular cavities in the Mammalia are in many instances modified to serve by the *odour* of their secretion as a means of defence, just as the part in question operates in the Cephalopods by reason of the *colour* of the ejected fluid.

When the ink-bag is laid open and well cleansed of its contents, its inner surface is seen to be composed of a fine cellular or spongy glandular substance: its exterior coat is of a tough white fibrous texture, and its outer surface commonly exhibits a peculiar glistening or silvery character.

The ink-bag probably attains its largest proportional size in the genus *Sepiola*, where it presents a trilobate form. It is of an oblong pyriform shape in *Sepia*, *Sepioteuthis*, and *Loligo*. It is relatively larger in *Sepia* than in *Octopus*, and the quantity of water which its contents will discolour is very surprising: it behoves the anatomist, therefore, to be very careful not to puncture this part during the dissection of a Cephalopod.

In the living Cephalopods the inky fluid is secreted with amazing rapidity; we have seen an Octopus, which had previously discoloured the water for a considerable extent around it, immediately after its capture continuing its black ejections several times in quick succession, and ultimately expelling in convulsive jets a colourless fluid, when the powers of secreting the black pigment were exhausted.

In every species of Cephalopod which possesses this organ, the tint of the secretion corresponds, more or less, with the coloured spots on the integument. The Italian pigment, called ‘Sepia,’ and the Chinese one, commonly called ‘Indian Ink,’ both of which are the inspissated contents of the organ above described, afford examples of different shades of this singular secretion.

If the Cephalopods are enabled thus to conceal themselves during the day, they have also the power, by means of another secretion, to render themselves conspicuous by night by means of a phosphorescent exhalation.‡

The Liver.—This gland is remarkable in the Cephalopods, as in the other classes of the Molluscous Sub-kingdom, for its great proportional size. In the Nautilus the liver (*q*, *q*, *fig*. 219) extends, on each side of the crop, from the œsophagus to the gizzard. There is a parallelism of form, as will be afterwards seen, between this gland and the Respiratory organs,

* Davy states that the secreted fluid is “a carbonaceous substance mixed with gelatine;” but, according to *Bizio*, this secretion yields on analysis a substance *sui generis*, which he calls ‘Melania.’ See *Edinb. Philos. Journal*, vol. xiv. p. 376.

† Lectures on Comp. Anat. vol. i. p. 398.

‡ See Oligerus Jacobæus de Sepiæluce, in the *Acta Hafniens.* vol. v. p. 283.

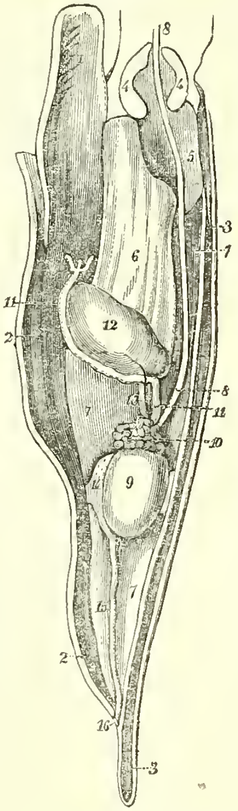
for it is divided into four lobes, and these are connected by a fifth portion, which passes transversely below the fundus of the crop. All these larger divisions are subdivided into numerous lobules of an angular form, which vary in size from three to five lines. These lobules are immediately invested by a very delicate capsule, and are more loosely surrounded by a peritoneal covering common to this gland and the crop.

The liver is supplied by large branches which are given off from the aorta, (*r*, *fig.* 219,) as that artery winds round the bottom of the sac to gain the dorsal aspect of the crop. It is from the arterial blood alone, in this, as in other Mollusks, that the secretion of the bile takes place, there being but one system of veins in the liver, corresponding to the hepatic, which returns the blood from that viscus, and conveys it to the vena cava at its termination. The colour of the liver is a dull red with a violet shade; its texture is pulpy and yielding. When the capsule is removed by the forceps, the surface appears under the lens to be minutely granular or acinous, and these *acini* are readily separable by the needle into clusters hanging from branches of the bloodvessels and duct. The branches of the duct arising from the terminal groupes of the acini, form, by repeated anastomoses, two main trunks, which unite into one at a distance of about two lines from the laminated or pancreatic cavity.

There appears to be one example in the Dibranchiate Order where the liver is divided into four lobes, as in the Nautilus; this occurs, according to Dr. Grant, in the *Loligopsis guttata;* but in the figure which is given of this structure the lobes are each distinct from the rest, and divided at the middle line; while in the Nautilus the four lobes are united together. Rathké, on the contrary, who has given an elaborate account of the Anatomy of *Loligopsis* under the name of *Perothis*,* describes and delineates the liver, in the two species of that genus dissected by him, as a simple undivided viscus, of an ellipsoid figure, situated in the middle line of the body (12, *fig.* 223). In *Onychoteuthis Banksii* the liver is a single elongated laterally compressed lobe, obtuse and undivided at both extremities. In the Sagittated Calamary it is single, elongated, and cylindrical. In *Sepia* and *Rossia* it is divided into two lateral lobes, both of which are notched at the upper extremity. In the Argonaut the two lobes are united for a considerable extent along the mesial line, but are greatly produced laterally, and advance forwards, narrowing towards a point, so as partially to enclose the alimentary canal. In *Octopus* the liver is a single oval mass, flattened anteriorly. In *Eledone* it presents a spherical form, corresponding to the ventricose form of the visceral sac. In the two latter genera the ink-bag is enclosed within the capsule of the liver, but in the Argonaut and in all the Decapodous genera this is not the case.

The proper capsule of the liver is very delicate, and apparently nothing more than the outer termination of the cellular tissue which connects the lobules of its parenchyma. When this is inflated from the biliary ducts, it is seen to be composed of cells, formed by the ultimate ramifications of the duct, with very thin parietes, and relatively larger than those of the liver of the Snail. This is the structure observable in the liver of the *Octopus*, according to Müller,* and Rathké observed the same structure in the terminal cœca of the hepatic duct in *Loligopsis*.

Fig. 223.



Viscera in situ, Loligopsis.
Lol. Eschscholtzii.

In the Octopodous Dibranchiates, which have a large crop, and the lower pair of salivary glands of correspondingly large dimensions, the two biliary ducts are simple canals, which are continued from the lower end of the liver, embracing the origin of the intestine, and uniting below it to terminate by a common orifice in the pyloric appendage. But in the Decapodous tribe they continue to send off branches, which subdivide and form clusters of cœcal appendages, through a greater or less proportion of their entire course. The follicles thus appended to the biliary ducts are larger than those which form the liver; they are figured by Monro in the *Loligo sagittata* as the ovary, but were considered by Mr. Hunter to represent the pancreas in the Cuttle-fish, from which species he took the preparation of these parts in his collection.† These follicles are described with much care and detail by Rathké in the genus *Loligopsis*, and, according to him, in one species (10, *fig.* 223), (*Lol. Eschscholtzii,*) they terminate, not in the hepatic duct, but separately and directly in the pyloric appendage. We have found these cystic follicles appended to the hepatic duct in *Sepiola*, *Onychoteuthis*, *Sepioteuthis*, and in the genus *Rossia*, in which they present the largest proportional development hitherto ob-

* Πηρωθης, *mutilatus*, a name applied to this genus by Eschscholtz, in consequence of the generally mutilated condition of the tentacles. See Mém. de l'Acad. Imp. de Petersbourg, tom. ii. pt. 1 & 2, p. 149.

* De Glandularum Struct. Pen. p. 71.

† See No. 775, *Physiological Catalogue*, 4to. vol. i. p. 229.

served in the class. Here the biliary ducts, as soon as they emerge from the liver, branch out into an arborescent mass of larger and more elongated follicles than those constituting the hepatic parenchyma; these ramifications extend full half an inch from the hepatic duct, and conceal the upper halves of both the stomach and pyloric appendage.

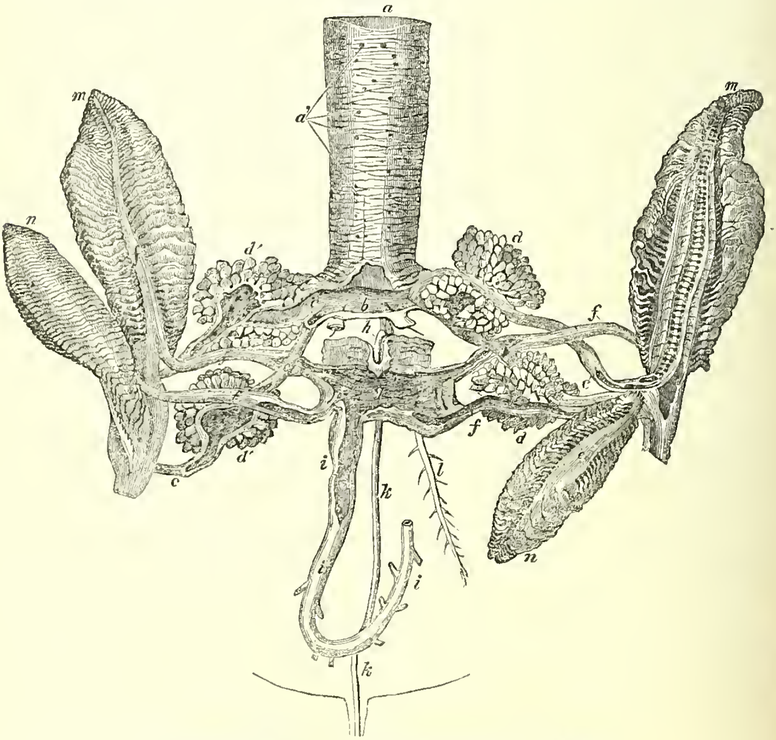
Organs of Circulation.— Prior to the dissection of the Nautilus Pompilius the Cephalopods were regarded as having three distinct hearts, a peculiarity which is not found in the circulating system of any other class of animals. In the Nautilus, however, there is but one ventricle, which is systemic, as in the inferior Mollusks; and the three hearts are, therefore, characteristic only of the Dibranchiate or higher order of Cephalopods.

These differences in the circulating system of the two orders are accompanied with equally well marked modifications of the respiratory organs; and hence the primary divisions of the class are each distinguished by characters of equal value, and derived from modifications of those organs which afford the most natural indications of the corresponding groups in the other classes of the Molluscous division of Invertebrate animals.

In the Nautilus the veins which return the blood from the labial and digital tentacles and adjacent parts of the head and mouth, terminate in the sinus excavated in the substance of the cephalic cartilage. From this sinus the great anterior vena cava (*a*, *fig.* 224) is continued, running in the interspace of the shell-muscles on the ventral aspect of the abdominal cavity, and terminating in a sinus (*b*) just within the pericardium, where it receives the venous trunks of the viscera. (These are indicated by bristles in the figure.)

The structure of the vena cava is very remarkable; it is of a flattened form, being included between a strong membrane on the lower or ventral aspect, and a layer of transverse muscular fibres, which decussate each other on the upper or dorsal aspect; both the membrane and the muscle pass across from the inferior margin of one shell-muscle to the other; they consequently increase in breadth as those muscles diverge, and complete the parietes of the abdomen on the ventral aspect. The vein, however, maintains a more uniform calibre by its proper internal coat, leaving a space on either side between the membrane and muscle. The adhesion of the proper membrane to the muscular fibres is very strong, and these, though extrinsic to the vessel, form part of its parietes on the dorsal aspect. There are several small intervals left between the muscular fibres and corresponding round apertures (*a'*) in the membrane of the vein and contiguous peritoneum, by which the latter membrane becomes continuous with the lining membrane of the vein: from this structure it would seem that the blood

Fig. 224.



Circulating and Respiratory Organs, Nautilus Pompilius.

might flow into the peritoneal cavity, or the fluid contents of that cavity be absorbed into the vein.*

In the structure of the other veins of the Nautilus nothing uncommon is observed: their principal termination is in the sinus above-mentioned, where the greater or systemic circulation ceases, if we are to consider the lesser circulation to commence where the blood again begins to move from trunks to branches.

Four vessels, which, according to the above view, are analogous to *branchial arteries*, (*c, c*,) arise from the sides of the sinus, and proceed, two on each side, to their respective gills. In this course they have each appended to them three clusters of short, pyriform, closely aggregated, glandular follicles (*d, d*). The larger cluster is situated on one side of the vessel, and the two smaller on the opposite. Each of these clusters is contained in a membranous receptacle communicating with the pericardium, and formed by partitions projecting from its inner surface. In these partitions we observed a fibrous texture, which conveyed an impression that they were for the purpose of compressing the follicles and of discharging such fluids as might exude through their parietes into the pericardium, whence it might be expelled by the papilliform apertures at the base of the gills into the branchial cavity.† The follicles, however, terminate by their proper apertures in the interior of the dilated parts of the vessels to which they are appended: (these are shewn on the right side at *d′*,*d′*.) We shall revert to these singular bodies in the description of the circulating organs of the *Dibranchiata*.

The branchial arteries having reached the roots of the gills become contracted in size, and their area is here occupied by a valve which opposes the retrogression of the blood. Each vessel, then, penetrates the fleshy stem of the branchia (*e*), where it dilates into a wide canal, which presents a double series of orifices through which the blood is driven by the contraction of the surrounding muscular substance, into the vessels which extend along the concave margins of the branchial laminæ.

The branchial vein (*f*) receives the aerated blood from vessels extending along the convex margins of the respiratory laminæ, by a series of alternate slits, and is continued down the anterior or inner side of the gill. After quitting the roots of the gills each vein crosses its corresponding artery on the dorsal aspect, and is continued, without forming a dilatation or sinus, to the systemic ventricle, where regurgitation is prevented by a single semilunar valve at the termination of each vein.

The ventricle (*g*) is of a somewhat compressed and transverse quadrate form: its muscular parietes are nearly a line in thickness, and present internally a decussated structure.

Two arteries arise from it; one superior and small (*h*), whose orifice is furnished with a double valve; the other inferior and of large size (*i*), coming off from near the left angle of the ventricle, and furnished with a muscular bulb about five lines long, at the termination of which there is a single valve; and which ought rather to be considered as a continuation of the ventricle. The lesser aorta gives off a branch to the great gland of the oviduct; a second, which is continued down the membranous siphuncle of the shell; and a third to the fold of intestine (*l*). The larger aorta passes downwards between the gizzard and ovary, and renders vessels to both these viscera. It then winds round the bottom of the pallial sac, sends off large branches to the liver, and gains the dorsal aspect of the crop, along which it is continued, distributing branches on either side to the great shell-muscles, to the cephalic cartilage, where it divides into two equal branches, which pass round the sides of the œsophagus, and furnish branches to the mouth, the surrounding parts of the head and the funnel.

In the *Dibranchiata* the veins of each arm form two principal branches, which descend along the lateral and posterior parts of those appendages; each lateral vein unites at the base of the arm with the opposite vein of the adjoining arm; the united vessel is joined by another similarly formed; and the whole of the venous blood is thus ultimately conveyed to an irregular circular sinus, from the anterior part of which, between the head and the funnel, the great anterior cava is continued. In the Octopus this vessel (*a*, *fig.* 226) is provided with two semilunar valves, where it communicates with the venous circle. A little below this part it receives the veins of the funnel; then those of the anterior part of the liver (*b*) and of its muscular envelope. Upon its entrance into the pericardium the vena cava divides without forming a sinus as in the Nautilus; and sometimes before, sometimes after its division it is joined by two large visceral veins (*c*). Thus reinforced, each of the divisions (*d, d*) proceeds downwards and outwards to the lateral or branchial heart of its corresponding side; but previous to opening into the ventricle it dilates into a sinus (*e*), which also receives the venous blood from the sides of the mantle and the fleshy and vascular stem of the branchia, by the vein marked *f*.

Both the divisions of the vena cava and the two visceral veins, after having entered the pericardiac or venous cavity, are furnished with clusters of spongy cellular bodies (*g, g*), which open into the veins by conspicuous foramina, like the venous follicles of the Nautilus above described.

In no species of Cephalopod which has hitherto been anatomized, have these appendages* been found wanting; but they vary in form in different genera. In the Genus *Eledone*† they

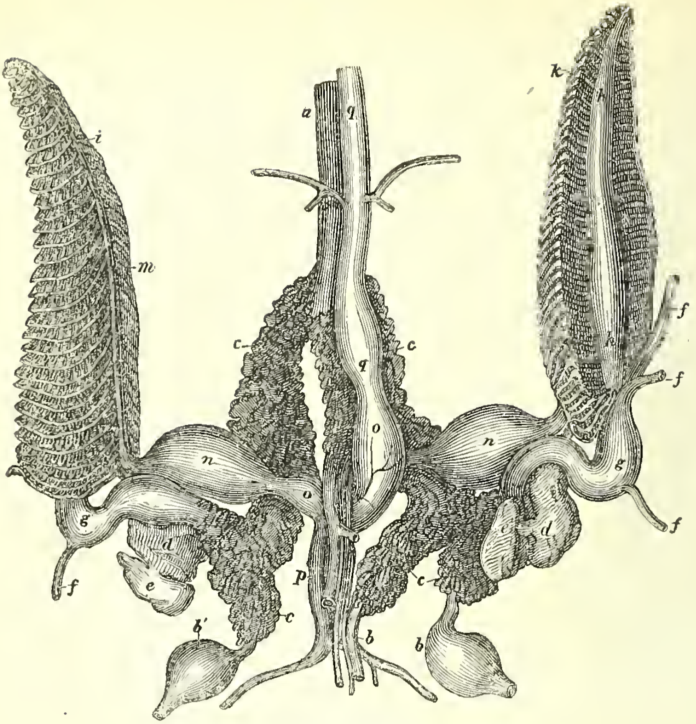
* For a further description of this structure, its analogies, and probable uses, see 'Memoir on the Pearly Nautilus,' p. 27 *et seq.*

† We found the pericardium in the specimen dissected filled with coagulated matter accurately moulded to the different parts which contained it.

* From a consideration of the different particulars given in Aristotle's anatomical description of the Cephalopods, Köhler supposes the part which he calls μύτις, *mytis*, to have been the glandular appendages of the veins above described.

† Carus, Vergleich. Zootomie, tab. iv. fig. viii. x, *Eledone Moschata*.

Fig. 225.



*Circulating and respiratory organs—Cuttle-fish.**

form thin colourless pyriform sacs, extending nearly an inch from the vein. They are arranged in distinct clusters, and are relatively shorter in *Argonauta*. In *Sepioteuthis* the whole extent of the superior and inferior trunks of the veins contained in the pericardium present an uniform and continuous cellular enlargement of their parietes. In *Loligo* the coats of the corresponding veins in like manner present only a spongy thickening. In *Sepia* the cells are more elongated, but are large, irregular, and flocculent (*c, c, fig.* 225), and continued without interruption not only upon the divisions of the vena cava (*a*), but upon the visceral veins, two of which (*b, b*) present remarkable dilatations.

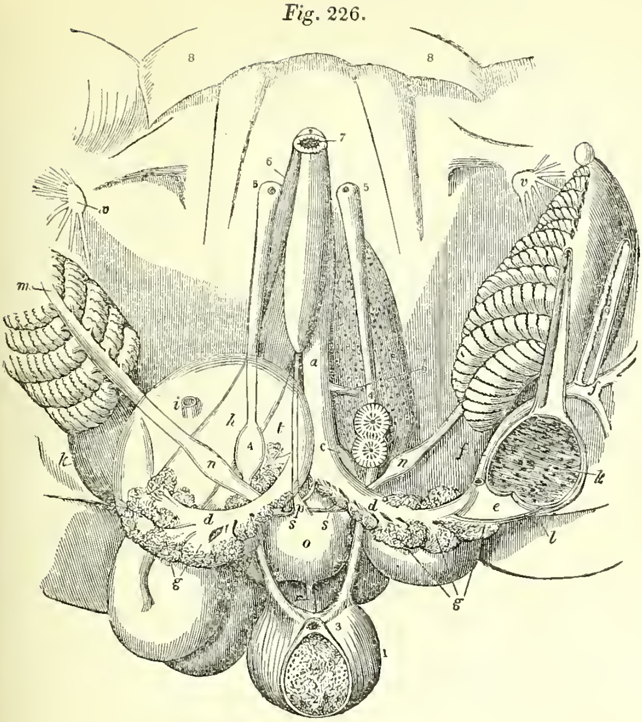
In *Loligopsis* the venous follicles are in distinct groups, as in Nautilus; and Rathké describes them as presenting a laminated and glandular structure.

With respect to the function of these bodies nothing is as yet definitely known. They are well supplied with blood from the neighbouring arteries, and are undoubtedly glandular; but the matter which they secrete has not yet been subjected to chemical analysis. If the spongy coats of the vena cava of a Calamary be pressed, a whitish fluid escapes, which is always thicker and more turbid than the blood which circulates in the vein. The elongated cells of the Poulp yield in like manner an opake and yellow mucus. Some physiologists suppose that the secreted matter is not expelled by the orifices of the sacs into the veins to be mixed with the current of blood, but that the venous blood passes into the cells by those apertures, and that the matter secreted from it exudes from the parietes of the cells or follicles into the great serous cavity surrounding them. Mayer, considering that the urine is secreted from venous blood in the lower vertebrate animals, regards these venous appendages as the renal organs of the Cephalopods; the serous sacs (*h, fig.* 226), therefore, which Cuvier calls the 'great venous cavities,' and which we have termed the 'pericardium,' the German Physiologist calls the 'urinary bladder;' and the papillary orifices (*i*) leading into the branchial or excrementory chamber, which we have compared with the orifices leading from the pericardium of the Ray and Sturgeon into the peritoneal cavity of the abdomen,† Mayer calls the urethræ. It must be observed, however, that this Physiologist does not advance any proof from chemical analysis in support of his theory. Cuvier, on the other hand, believing that the water of the branchial chamber might have access by the orifices to the cavities containing the appendages in question, supposes that they

* From Home's Comparative Anat. vol. iv. See the original figure and description by Hunter, in Descr. Catalogue of Mus. R. Coll. of Surgeons, vol. ii. pl. xxii.

† Memoir on the Nautilus, p. 33.

Fig. 226.



*Viscera of Poulp.**

and decussating carneæ columnæ (*k, fig.* 226), and where they communicate with the venous sinus two semilunar valves (*l*) are placed to prevent regurgitation. Their function is to accelerate the circulation through the branchiæ; and by this simple addition to the respiratory apparatus, the two gills of the Dibranchiata are rendered equal to the office of preparing the blood to maintain the increased muscular exertions, and repair all the corresponding waste which the vital economy of this highly organized group of Molluscous animals occasions.

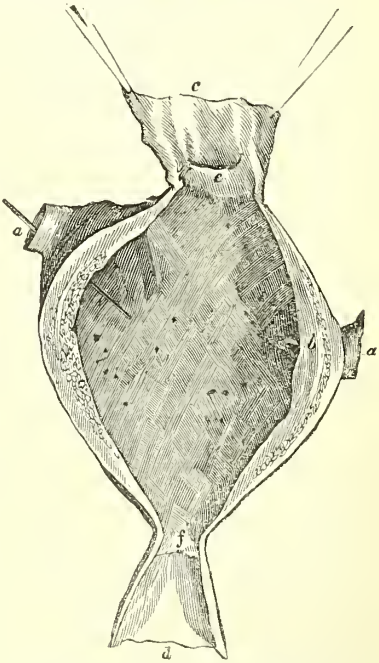
The branchial veins (*m, m, figs.* 225, 226) return, as in the Nautilus, along the internal or unattached side of the commissure of the branchial laminæ; and, as they approach the systemic ventricle, generally dilate into a sinus (*n*)

may serve as accessory respiratory organs. The valvular structure of the orifices is opposed, however, to this view; while it supports the doctrine of their being excretory outlets.

The venous follicles may, therefore, serve as emunctories, by means of which the blood is freed of some principle that escapes from their external pores; or they may alter the blood by adding something thereto; or, like the spleen, they may assist in converting arterial to venous blood. As a secondary function they may serve as temporary reservoirs of the venous blood whenever it accumulates in the vessels either from a general expansion, or from a partial impediment in its course through the respiratory organs; and thus the cells or follicles, which are endowed with a motion of systole and diastole, like the auricles of the heart, may serve to regulate the quantity of blood transmitted to the gills.

The branchial ventricles (*d, d, fig.* 225) are appended to the roots of the gills: in the *Octopoda* they are simple pyriform muscular cavities (*k, k, fig.* 226,) generally of a blackish grey colour; in the *Decapoda* they are elliptical or transversely oblong, of a light grey or pale red colour, and have a white fleshy appendage (*e, e, fig.* 225,) hanging to their lower surface or their external side. The connecting pedicle is hollow, and communicates with a small cavity in the substance of the appendix. Internally these ventricles are deeply impressed with cells

Fig. 227.



Systemic Ventricle, Onychoteuthis.

* From Mayer, Analecten für Vergleichende Anatomie, tab. v.

on each side: these sinuses are relatively larger in the *Sepia* than the *Octopus*. In both species the branchial vein resumes its ordinary dimensions before terminating in the ventricle; but in the Cuttlefish the sinus is placed closer to the ventricle.

The systemic ventricle *(o)* is situated in the mesial plane between the bifurcation of the vena cava above, and the ovary or testis below. In the *Octopus* and *Eledone* it presents a globular form, rather extended tranversely, and with the branchial sinus entering at its superior and lateral aspects. In the *Loligo* and the *Onychoteuthis (fig.* 227) it is lozenge-shaped, with the long axis in the axis of the body; giving off the two aortæ *(e, d)* by the anterior and posterior angles, and receiving the branchial veins *(a, a,)* at the lateral angles. In the *Sepia*, *(o, fig.* 225,) *Sepioteuthis*, and *Rossia*, the systemic ventricle is a fusiform body, bent upon itself at right angles. About one-half on the right side lies in the axis of the body, the remainder extends transversely to the left side; the extremity of this part receives the left branchial vein, the other extremity gives off the anterior aorta *(q, fig,* 225). The bulb of the posterior and generally the larger aorta *(p, fig.* 225) is continued from the middle of the transverse portion; the right branchial vein enters the middle of the right side of the longitudinal portion of the ventricle.

In all the *Dibranchiata* the parietes of the systemic heart, though thin, are firmer and more muscular than those of the branchial hearts; and its cavity is generally about three times greater than that of either of the others: its inner surface shows the regular interlacement and decussation of the columnæ carneæ, none of which, however, project into the cavity. The termination of each branchial vein is defended by a pair of membranous semilunar valves *(b, fig.* 227). The origin of the lesser aorta *(p)*, arising from the anterior part of the ventricle, is defended by a single valve *(e, fig.* 227); that of the great aorta, *(q′, fig.* 226,) which, though posterior in its origin, is destined to supply the head and anterior parts of the body, is generally provided with a muscular bulb, as in the Nautilus. In the Octopus it is defended, according to Cuvier, by two semilunar valves; but in the Calamary and Onychoteuthis by a single valve *(f, fig.* 227). In the Octopus there is also a third small artery *(r, fig.* 225) given off directly from the ventricle, which is distributed to the generative organs, and presents considerable periodical variations of size in relation to the functions of those parts. In the same genus the small aorta, which arises from the anterior part of the ventricle, first gives off two long and slender branches *(s, s, fig.* 226), which are distributed to the venous follicles, whose arterial vascularity we have before mentioned. The trunk then divides into two arteries, of which the largest *(t)* ascends in front of the vena cava to be distributed to the mantle; the other supplies the folded intestine and surrounding peritoneum. The large aorta first passes backwards and to the right between the layers of peritoneum which separate the intestinal sac from that of the pyloric appendage and that of the stomach; winds round the latter, and passes, by a proper opening, to the right of the cardia through the muscular septum, and into the cavity behind the liver, and ascends on the right side of the dilated œsophagus to the cartilaginous cranium. Here, after distributing branches to the surrounding parts, it bifurcates and completely encircles the gullet; and from this vascular ring, which is strikingly analogous to the branchial arches in Vertebrata, the head and all its complex radiating appendages derive their nutriment.

Respiratory Organs.—The branchiæ present the same general form and structure in both orders of Cephalopods, but differ, as before observed, in number, and also in their mode of attachment to the mantle. They are always entirely concealed and protected by the mantle, which is extended forwards so as to form a peculiar chamber for them anterior to the other viscera, and into which the rectum and generative organs open. It is interesting to perceive the respiratory cavity retaining, in the highest organized Mollusks, that relation with the anal extremity of the digestive canal which we trace through the whole of this type of animal conformation, and which forms so well-marked a line of distinction between the Molluscous and Vertebrate divisions of the animal kingdom.

In the Nautilus the four branchiæ are attached by their bases only to the inner surface of the mantle; but in the Dibranchiates a thin fibrous membrane connects the fleshy stem of each gill to the contiguous surface of the mantle. In the Nautilus the branchiæ are subject to contortions from the want of this support; and in the specimen which we dissected, we found the gills on one side closely bent upon themselves, with their apices turned down; this circumstance does not probably impede a circulation which flows with an equable and continuous current through the gill; but where the blood is driven in jerks by the contractions of a powerful ventricle, a necessity then exists for the provision of a free channel for the passage of the fluid; and accordingly we find that the obstruction of the branchial artery by the bending of the fleshy stem of the gill is obviated by the simple but effectual means above described, viz. the superaddition of a connecting membrane, which always preserves the gill in a straight position.

In both orders of Cephalopoda the branchiæ present an elongated pyramidal figure, with their apices directed forwards: they are compressed from before backwards in the Nautilus *(n, m, fig.* 224), and from side to side in the Cuttle-fish *(i, k, fig.* 225) and most other Dibranchiates. They are composed of a number of triangular vascular laminæ extending transversely from each side of a central fleshy stem *(h, fig.* 225), having an alternate disposition: each lamina is composed of smaller transverse laminæ, which are again similarly subdivided; the entire gill thus exhibiting the structure called by botanists 'tripinnate,' by which an extensive surface is afforded for the minute division of the branchial vessels.

In the Nautilus (*fig*. 224) there is a larger and smaller branchia on each side; the larger and external branchia (*m*) presents forty-eight pairs of laminæ; the smaller branchia (*n*) thirty-six.

In the Dibranchiates the gills vary in the relative size and number of laminæ in different genera; they are, perhaps, proportionally smallest in the *Loligopsis*, where, according to Rathké, the number of branchial laminæ does not exceed twenty-four pairs; and it is interesting to observe in this genus that the muscular structure of the mantle has a correspondingly feeble development. In the Cuttle-fish the brauchiæ are each composed of thirty-six pairs of triangular laminæ: in the Sagittated Calamary of sixty pairs of laminæ.

As the branchiæ of the Cephalopods are unprovided with vibratile cilia, respiration is effected by the alternate dilatation and contraction of the branchial chamber; in the first action the sea-water rushes in by the anterior aperture of the mantle; by the second it is expelled through the cavity of the funnel. As in other classes, respiration is performed more quickly in the young than in the full-grown animals: Dr. Coldstream witnessed an Eledone, which measured one inch and a half in length, respire eighteen times in a minute; while one of the same species, which measured four inches in length, respired ten times in a minute. The proper direction of the respiratory currents is insured by various mechanical contrivances; in the Nautilus, the funnel passes through a hole in the substance of the mantle, which fits it so closely, that at the moment when the funnel is distended by the expiratory stream, no space is left external to it by which the water can escape; and the greater the force by which the water is driven into the funnel, the closer is it girt by the mantle. In the Poulp and Eledone, where the funnel is connected to the fore part of the neck, and the mantle passes across its base, two large valvular folds (one of which is shown at *v*, *fig*. 216) are extended from its sides; these are concave towards the respiratory sac; they subside during inspiration, and the parietes of the funnel at the same time are collapsed; the latter during expiration are dilated, while the valves are raised and expanded, and thereby prevent the ejected currents from passing outside the funnel. In the Argonaut, and in all the Decapods, except the Loligopsis and Cranchia, the sides of the funnel are articulated to the opposite sides of the mantle by ball-and-socket joints, which produce so close an apposition of the anterior free margin of the mantle with the parts it surrounds, that upon its contraction, no other outlet, save the funnel, is left for the expiratory currents. In the Argonaut the pallial eminence is a round tubercle, below which is a small cavity, and these are adapted to a cavity and tubercle of corresponding form at the side of the funnel. In Sepia, the articular tubercle is elongated in the direction of the axis of the body, and is of an oval form. In Loligo and Onychoteuthis it is still more elongated and narrow, and the articular depression is conformable: in Loligopsis the corresponding cartilage is no longer subservient to an articulation with the funnel, but is represented by a series of wart-like knobs.

Tegumentary System.—The skin of the Cephalopods is thin and lubricous, and can be more easily detached from the subjacent muscles than in the inferior Molluscous classes. In the Poulp, Eledone, Argonaut, Cuttle-fish, and Sepiola, its texture is soft and tender, and the whole mantle is semitransparent in some species, as the *Octopus hyalinus;* but in the Calamaries and Onychoteuthides it is thicker, harder, and more unyielding; it is interesting to observe that it is in these latter genera that the epidermoid system is most developed, as is exemplified in the horny denticulations and hooks upon the acetabula.

In the Cuttle-fish the suckers are provided with simple unarmed horny rings. In the Octopods the epidermis is reflected over the interior of the suckers without being thickened into a horny substance at that part. In the body generally the *epidermis* is readily detached by maceration, and forms a thick, white, elastic, semitransparent, external layer.

The colorific stratum of the integument forms, both in its structure and vital phenomena, one of the most curious and interesting parts of the organization of this singular class of animals; and the nature of which, when thoroughly understood, may be expected to elucidate the mysterious operations of light in producing and affecting the colours of animals.

This stratum, which is analogous to the *rete mucosum*, consists of a very lax and fine vascular and nervous cellular tissue, containing an immense number of small closed vesicles, which vary in relative sizes in different species of Dibranchiata. These vesicles are of a flattened oval or circular form, and contain a fluid in which is suspended a denser colouring matter. The colour is not always the same in all the vesicles, but in general corresponds more or less closely with the tint of the secretion of the ink-bag. This, for example, is the case in *Sepiola*, in which all the vesicles contain material of the same colour. In *Sepia*, besides the vesicles which correspond to the ink in the colour of their contents, there is another series of an ochre colour. In *Loligo vulgaris* there are three kinds of coloured vesicles, yellow, rose-red, and brown. In *Loligo sagittata* there are four kinds, saffron, rose-red, deep blue, and light blue. In *Octopus vulgaris* there are also four orders of vesicles, viz. saffron, red, blackish, and blueish. The *Argonauta Argo* possesses vesicles of all the colours which have been observed in other Cephalopods, and hence the variety and change of colour which the surface of its skin presents when exposed to the light.

These vesicles have no visible communication either with the vascular or the nervous systems, or with each other: yet they exhibit, during the life-time of the animal, and long after death, rapid alternating contractions and expansions.* If, when the animal is in a state

* Conf. Dr. Coldstream in Edinb. Journal of Natural and Geographical Science, vol. ii. p. 297.

of repose, and the vesicles are contracted and invisible, the skin be slightly touched, the coloured vesicles show themselves, and in an instant, or sometimes with a more gradual motion, the colour will be accumulated like a cloud or a blush upon the irritated surface. If a portion of the skin be removed from the body and immersed in sea-water, the lively contractions of the vesicles continue; when viewed in this state under the microscope by means of transmitted light, the edges of the vesicles are seen to be well defined, and to pass in their dilatations and contractions over or under one another. If the separated portion of integument be placed in the dark, and examined after a lapse of ten or fifteen minutes, all motion has ceased; but the vesicles, when re-exposed to a moderately strong light, soon, in obedience to that stimulus, recommence their motions. As the vibratile microscopic cilia have been recently traced through the higher classes of the animal kingdom, it is not an unreasonable conjecture that equally inexplicable motions of the colouring parts of the integument may also be detected in other classes than that in which we have just described them, and thus a clue may be obtained towards the explanation of the influence of geographical position on the prevailing colours of the animal kingdom.

Besides the colouring matter, another kind of product is secreted between the corium and cuticle, viz. the shell: this presents different degrees of development in different genera. M. De Blainville in France, and Leach, Broderip, Gray, and Sowerby, among the able naturalists of our own country, maintain that the Argonaut shell is not the product of a Cephalopod, but of some inferior Mollusk, allied to the Carinariæ, whose shell *Linnæus* indeed placed in the same genus with the Argonauta, in consequence of the close relationship subsisting between them, both in form and structure. The principal grounds for this opinion are the following. The Ocythoë has no muscular or other attachment to the Argonaut shell. When captured, and placed alive in a vessel of sea-water, it has been seen voluntarily to quit the shell, and in one instance without manifesting any disposition to return to it. In this state, viz. without its shell, it was described by Rafinesque as a new genus of Cephalopod under the name of *Ocythoë*, and De Blainville, who first recognized this genus as being founded on an animal identical with the Cephalopod of the Argonaut, or the *Nautilus primus* of the ancients, retained the name in order to distinguish the supposed parasite from the shell which it had, according to this theory, adopted. Agreeably with the absence of any natural connexion between the Ocythoë and the shell in question, is the fact that this animal is not found in any constant or regular position in the shell. In most examples we have found the funnel and ventral aspect of the body turned towards the external wall of the shell, as in the figure (*fig.* 206). The Cranchian specimen figured by Mr. Sowerby was in the same position. In the specimen which M. De Blainville* has carefully delineated for this purpose, the back of the Ocythoë is next the involuted convexity of the shell, the funnel is towards the opposite expanded concavity, but turned out of the middle line, and separated from the parietes of the shell by the retracted feet. In the figure which illustrates Broderip's excellent Memoir,† the animal is represented with the funnel next the involuted crest of the shell. In another specimen in the unique collection of the same Naturalist, the Cephalopod is retracted on a mass of ova, its arms huddled together, and its funnel projecting from the middle of one side of the shell; on the opposite side numerous suckers are seen expanded and applied to the inner surface of the shell, demonstrative of the abnormal mode of its adhesion to that body.

Whatever be the position in which the Ocythoë is found, the whole of the exterior surface of its mantle is coloured as in the naked Cephalopods, which seems to indicate that it has not been permanently excluded from light by an opake calcareous covering, such as the Argonauta shell must have formed if it had been applied to the body of the Ocythoë *ab ovo*. What is more remarkable, and contrary to the analogy of true testacea, is, that there is little or no correspondence between the disposition of the colour of the Ocythoë and that of the Argonaut shell. The external surface of the skin of the Ocythoë has the same entire epidermic covering as in the naked Poulp, yet the Argonaut shell is furnished with a delicate epidermis in its natural state.

All Mollusks which are naturally provided with external shells have them for protecting either a part or the whole of the body; and in the latter case the interior of the shell is always kept clear, that the animal may retire to it for safety; but this retraction into the hollow of the shell is impossible to the Ocythoë, at least in those numerous cases in which the shell is found more or less filled with masses of ova. Other Cephalopods, with external shells, indubitably their own, as the Pearly Nautilus, have adequate muscular attachments; and it may reasonably be asked does the Argonaut afford a valid exception to this rule?

Such an exception indeed it must form if the shell be really secreted, as the Continuator of Poli asserts, by the Cephalopod inhabitant; and not only in this particular, but in every principle which has been established in reference to the relations of a shell to the body and the reciprocal influences affecting them in the Molluscous classes.

The naturalists who maintain that the Cephalopod of the Argonaut and the shell are parts of one and the same animal, insist on this undeniable fact, that from the time of Aristotle to the present day the Argonaut shell has never been found with any other inhabitant than the Ocythoë; and, what is of more weight, that the Ocythoë has never been found in any other shell than the Argonauta. Whereas the Hermit-Crab

* Malacologie, tom. ii. p. 1.
† Zoological Journal, vol. iv.

adopts different species as they happen to fall in his way. And further, that the different species of Argonauta, as the *A. Argo*, *A. tuberculata*, and *A. hians*, have each different species of *Ocythoë*. We may add that the light fragile texture of the Argonauta shell, like that of Carinaria, bespeaks a floating oceanic species, and not a Mollusk that creeps at the bottom, and therefore the probability is less that its real inhabitant should have escaped the notice of the Naturalist, supposing the Cephalopod to be a parasite.

In the posthumous volume of Poli's great work on the Sicilian Testacea, it is stated that that naturalist watched the daily development of the ova of an Ocythoë contained in an Argonaut shell, and that, by means of the microscope, he detected the rudiment of the shell in the embryo: the completion of the experiment was, however, accidentally interrupted; and the figure which the editor Della Chiaje has published of the ovum, which it was hoped would have determined the question, seems to shew the yolk appended to the embryo instead of the shell.

Mr. Gray,* on the other hand, has recently stated that the nucleus of the Argonaut shell, or that part which, from analogy, must have been formed in the egg, is too large to have been formed in the egg of the Ocythoë. The arguments drawn from the microscopical examination of the ova of the Ocythoë before the commencement of the development of the embryo, are obviously inconclusive; since, whatever the subsequent products of the egg might be, at this period only the granular and oily particles of the vitelline nidus could be expected to be seen.

With respect to another argument against the legitimate title of the Ocythoë to the shell, founded on the supposed uniform occurrence of a deposition of eggs in the same shell, we can adduce three exceptions in which the Argonaut shell was exclusively occupied by the Cephalopod; these specimens were taken along with several others, by Captain P. P. King, R.N., from the stomach of a Dolphin, caught upwards of six hundred leagues from land, and were kindly presented to us by that gentleman. In these examples, as in others, we were struck with the exact correspondence between the size of the shells and that of their inhabitants, every trifling difference in the bulk of the latter being accompanied with proportional differences in the shells which they occupied. The consideration of all these circumstances has prevented a satisfactory conclusion being formed with respect to this long-agitated and nicely-balanced question, and we are compelled to repeat after the Stagyrite, περὶ δὲ γενέσεως καὶ συναυξήσεως τοῦ ὀστράκου ἀκριβῶς μὲν οὔπω ὦπται.† Observation of the development of the Ocythoë until the period when it is excluded from the egg, would decide the point.

* See Proceedings of the Zoological Society, September, 1834.

† "But as touching the generation and growth of the shell nothing is as yet exactly determined."—*Hist. Anim.* lib. ix.

But this must be done satisfactorily, and with the requisite knowledge, care, and good faith on the part of the observer.

Before, however, quitting this subject, we will mention one example of a naked Cephalopod, nearly allied to Ocythoë, having manifested a parasitic propensity similar to that which is laid to the charge of that genus. A medical gentleman, (Dr. Moffat, of the Hon. East India Company's Ship, Flora,) who had collected objects in Natural History in the East Indies, amongst other specimens brought home an Octopus, which was caught in the Madras roads in his presence, by means of a baited hook and line, and, when drawn out of the water, was found to have its ventricose body firmly imbedded in a ghee-bowl, (one of the small round pots in which the fluid butter is brought on board ship,) which had been thrown overboard. The Doctor disengaged the Cephalopod from the bowl before placing it in spirits, and when we related to him the interest which the fact possessed in consequence of the problematic nature of the Argonaut shell, of which he was not before aware, he regretted much that he had not preserved the Octopus in the singular domicile which it had chosen. Another instance of the parasitic appropriation of a dwelling-place by a Poulp is related by M. Desjardins, in the Report of the Natural History Society of the Mauritius; he found an *Octopus Arenarius* in the shell of a *Dolium*.

The parasitic occupation of shells by the Octopi for the purpose of depositing the ova in them was not unknown to Aristotle. Καὶ ἀποτίκτει ὁ μὲν πολύπους εἰς τὰς θαλάμας ἢ εἰς κεράμιον ἤ τι ἄλλο κοῖλον ὅμοιον, &c. "And the Polypus oviposits in cavities or in *shells*, or some such hollow places."*

To return to the shells of the Dibranchiate Cephalopods; these, then, with the doubtful exception of the Ocythoë, are always internal, and either camerated and siphoniferous, or laminated and more or less rudimental, and concealed within the substance of the mantle.

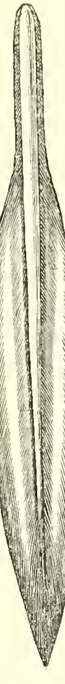
In *Octopus* and *Eledone* the traces exist in the form of two small amber-coloured styliform bodies, lodged loosely in capsules, (imbedded in the sides of the mantle,) and extending downwards from the insertion of the shell muscles, close to the base of the branchiæ. When the capsules are laid open, the styles frequently fall out in pieces, being of a friable texture. In the *Octopus* the styles are straight and elliptical; in *Eledone* they are largest at their upper extremities, and become filiform as they pass in a curved direction downwards.

In all the *Decapoda* in which the shell is rudimental, it is represented by a single piece lodged in the middle line of the dorsal region of the mantle. It is of a horny texture in all the genera except the Sepia, and has generally more or less the form of a feather, as in the Calamary (*fig.* 228), or of a straight three-edged sword.

* Hist. Anim. v. c. 16.

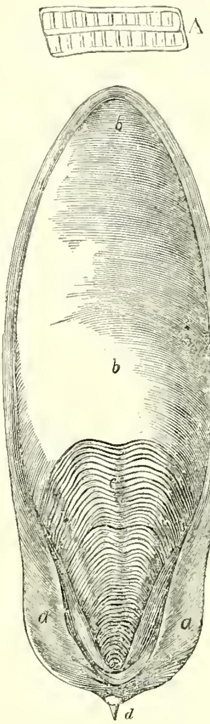
According to Aristotle the hard dorsal body of the Cuttle-fish was called by the Greeks ‘sepion,’ that of the Calamaries ‘xiphos.’* In *Sepiola* and *Rossia* the gladius does not reach half-way down the back, beginning at the anterior margin of the mantle, which in the latter genus is free. In *Loligopsis*, *Cranchia*, *Onycoteuthis*, and *Loligo*, it extends the whole length of the posterior part of the mantle. In *Sepioteuthis* it rivals in breadth the Sepium or Cuttle-bone, but is horny and elastic, as in the Calamary. In the latter the gladius is multiplied by age, and several are found packed closely one behind another in old specimens.

Fig. 228.



Gladius of the Calamary.

Fig. 229.



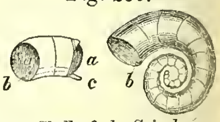
Rudimental Shell of the Cuttle-fish.

The Sepium or Cuttle-bone (*fig.* 229) is a well-known substance, and formerly figured in the Materia Medica as an antacid. It is a light cellular calcareous body, of a peculiar form and structure; and, as it is confined exclusively to the genus *Sepia*, its presence alone serves to characterise that section of Cephalopods. Its form is an elongated oval, depressed, convex on the dorsal surface, partly convex and partly concave on the opposite side: it terminates posteriorly in a very thin, dilated, aliform margin (*a*, *a*), partly calcareous and partly horny, which becomes narrower as it advances forwards, and is gradually lost in the sides of the shell. As this margin is inclined towards the ventral aspect, it produces at the posterior and ventral side of the shell a wide and shallow concavity, comparable to the chamber of the Nautilus shell which protects the body of that species: if the free margin of the sepium were in like manner produced beyond the previously deposited layers, it would advance from the posterior and lateral aspects of the animal, and cover the ventral surface, as in the Nautilus, leaving the convexity produced by the chambered portion projecting into the back. The thickened part of the sepium (*b*) which retains that situation, is in fact composed of a series of thin parallel calcareous plates, successively deposited and extending obliquely forwards from the ventral to the dorsal surface: the last formed plate is the most internal and the broadest, but not the longest also, as in the Nautilus; its development being limited to the anterior part of the shell, so that the previously deposited layers appear successively behind it forming irregular sinuous transverse striæ (*c*). The intervals of the plates are occupied by crystalline fibres, passing perpendicularly from one layer to the other: A is a magnified view of this structure. At the posterior part of the sepium, a little anterior to the thin margin, a pointed hooked process projects backwards: this differs in size and shape in different species of *Sepia;* but it is always characteristic of the peculiar production which has been described, and has served to identify some doubtful fossils.

As our present observations are limited to the recent species of *Cephalopoda*, we pass over the Belemnites, which are fossil internal shells of extinct animals of this order, to speak of that of the Spirula. This is a small recent Cephalopod, respecting the precise form and organization of which nothing is yet satisfactorily known. The only entire specimen which has been brought to Europe was taken by Péron, a French Naturalist, as it floated dead in the Tropical Ocean, between the Moluccas and the Isle of France; it has been described and figured by Roissy, Péron, and Lamarck; but both the figures and descriptions of these authors differ, and the specimen now no longer exists to determine the accuracy of either of the accounts. All agree, however, in stating that part of the shell was concealed within the body of the animal; and this fact is confirmed by a mutilated specimen in our own possession, and by one in a similar condition in the British Museum.

The shell of the Spirula (*fig.* 230) is about an inch in diameter, symmetrical, convoluted on one plane, with the whorls disjoined: it is composed of a succession of small regularly formed chambers, separated by partitions (*a*, *a*), which

Fig. 230.



Shell of the Spirula.

* “Τῇ μὲν οὖν σηπίᾳ, καὶ τῇ τευθίδι καὶ τῷ τεύθῳ ἐντός ἐςι τὰ στερεὰ ἐν τῷ πρανεῖ τοῦ σώματος, ἃ καλοῦσι τὸ μὲν σήπιον, τὸ δὲ ξίφος. Sub dorso firma pars Sepiæ Loligini ac Lolio continetur; illius *sepium*, horum *gladium* vocant.—*Hist. Animal.*, lib. iv., c. 1. 12mo. Ed. Schneider.

are concave towards the outlet of the shell, and are perforated by a siphon (*b*), the membranous tube of which is protected by a series of funnel-shaped calcareous sheaths (*c*), which are continued from the hole of one septum into that of the next, throughout the shell. The shell is white, lined with a nacrous layer within, and partially covered by a straw-coloured epidermis without. The organization of the Spirula may be expected to be in some respects intermediate to the Nautilus and Sepia, and an opportunity of investigating its internal structure is therefore highly desirable. According to Lamarck the animal is a Cephalopod with eight feet and two tentacles, like a Cuttle-fish, all provided with suckers; the body shaped like a purse and terminated behind by two lobes.

Although the siphoniferous shells are not confined to the Tetrabranchiate Order, yet it is in this division, as in the Pearly Nautilus for example, that we find this singular testaceous production to have arrived at the maximum of its development: it is covered by an epidermis, and, in the living animal, is also probably partially overlapped by a reflected portion of the thin and extensible mantle; but no part of it is buried in the substance of the animal, whose entire body, on the contrary, is inclosed in the last large expanded chamber. The relative position of the soft parts to this chamber we had not the means of determining from the specimen dissected by us, as this had been removed from its shell by Mr. Bennett, its fortunate captor, before it was placed in spirits. According to this able naturalist's statement, however, the ventral surface of the body and funnel was applied to the concavity of the outer expanded wall of the chamber; and the concavity behind the cephalic disk was adapted to the involuted convexity of the shell, and abutted against the ridge which rises from that part.* The camerated portion of the shell, according to Mr. Bennett, contained water or a liquid; but the size, condition, and contents of the membranous tube were not observed by him. The external form of the soft parts supported Mr. Bennett's account of their relative position to the shell; but some circumstances appeared to militate against the fluid nature of the contents of the deserted chambers. In the description of this specimen, we accordingly stated our belief that the chambers are naturally filled by a gaseous exhalation or secretion of the animal, and that the liquid is contained in the dilatable siphon which is extended from the posterior part of the animal's body, and passes through the central apertures of the different septa of the shell. From the communication which this siphon has with the pericardial cavity, it can be influenced, as to the quantity of fluid which it contains, by the actions of the Nautilus itself. A pneumatic and hydraulic apparatus for effecting the rising and sinking of the shell and its inhabitant is thus established, and Dr. Hooke's ingenious conjecture of the use of the camerated part of the shell is confirmed;* but the relative positions of the gas and water would, according to the above opinion, be the reverse of what Parkinson† supposed them to be. The full development of the theory of chambered shells, considered as hydrostatic instruments, is, however, in abler hands than ours; and the reader will be gratified to learn that it forms the subject of a portion of the forthcoming Bridgewater Treatise by Dr. Buckland.

* M. De Blainville, in a learned Memoir on the Structure of the Shells of Spirula and Nautilus, states his opinion that the true position of the animal of the latter shell is the reverse of that described above: this opinion has been adopted by some Naturalists of this country, but the analogies by which it is endeavoured to be supported are too remote and vague to enforce conviction.

Nervous System.—In tracing the development of the Nervous System through the Heterogangliate or Molluscous type of Organization, we find in the Gasteropodous genera which approach nearest to the Cephalopodous or highest division, that the ganglions which are concentrated about the head, are arranged in three groups: one, which is supraœsophageal, supplies the sentient organs, as the eyes and feelers; a second, which is subœsophageal and anterior, supplies the buccal apparatus; a third, which is subœsophageal and posterior, is the centre from which the sensitive, motive, and plastic nerves of the trunk originate. The anterior or buccal ganglions are united together, and to the cerebral ganglions, forming a nervous collar around the œsophagus; a similar collar is formed by the corresponding intercommunicating chords of the posterior subœsophageal ganglia.

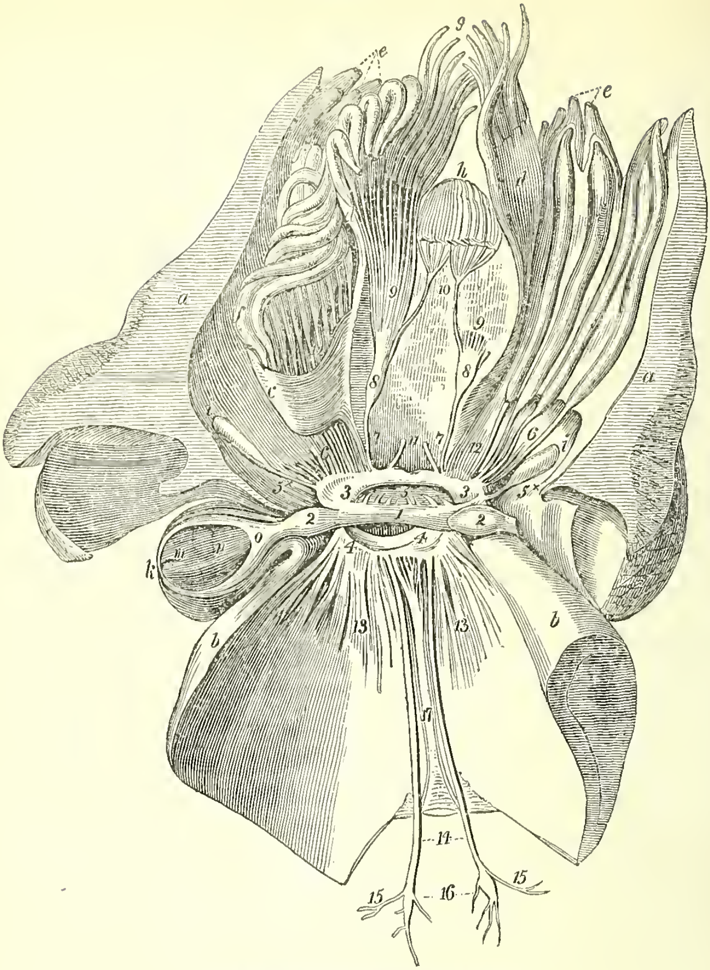
In the Cephalopods the nervous system is disposed on the same general plan, but the nervous substance is accumulated in a greater degree at the different centres of radiation, according to the superior development of the parts that are to be supplied therefrom.

In the Tetrabranchiate Order the principal parts superadded to the structure which we observe in the Gasteropodous Mollusk are those locomotive and prehensile organs which surround the buccal apparatus; and the chief modification of the nervous system is therefore seen in the enlargement of the oral ganglia and collar, and their close approximation to the cerebral ganglion. This part is comparatively little advanced, since the organs of sense which it immediately supplies, retain the same simple structure as in the inferior class of Mollusks, and are only augmented in bulk. The brain therefore is represented by a thick round tranversely extended chord (1, *fig.* 231), communicating at its extremities with the anterior and posterior œsophageal collars (3, 4), and with the small optic ganglions (2, 2), which supply the simple pedunculated eyes. Four small pairs of nerves (5) also pass from the supraœsophageal band to the fleshy mass supporting the mandibles. The cranial cartilage seems in the Nautilus to be principally developed with reference to the strong muscular masses to which

* Philosophical Experiments and Observations, p. 307.

† Organic Remains, vol. iii. p 102.

Fig. 231.



Nervous System of the Pearly Nautilus.

it affords a fixed point of attachment, and is not extended upwards so as to inclose the brain : this part is defended by a strong membrane which loosely surrounds it; but the extremities of the transverse band, the optic ganglions, and the anterior œsophageal collars rest in grooves of the cranial cartilage.

The nerves which arise from the anterior collar are very numerous: the larger branches (6, 6) enter respectively the roots of the tentacles which are lodged in the digital processes: the ophthalmic tentacles are also supplied from this source (5*); no lateral connecting filaments are found between these nerves, corresponding to those which associate the corresponding nerves of the Poulp for the simultaneous action of the parts they supply. Below the digital nerves small nerves are given off (12), which enter the external labial processes, and penetrate in a similar manner the roots of the tentacles which are there lodged. The internal labial processes are, however, supplied in a different manner: a larger nerve (7, 7) comes off on each side near the ventral extremity of the ganglion, and after a course of half an inch swells out into a flattened ganglion* (8, 8), from which numerous filaments (9, 9) extend into the substance of the process, and are continued into the tentacles as in the preceding case ; a larger twig (10) inclines inwards and distributes filaments to the olfactory laminæ. The infundibular nerves (11) come off near the lower part of the anterior collar.

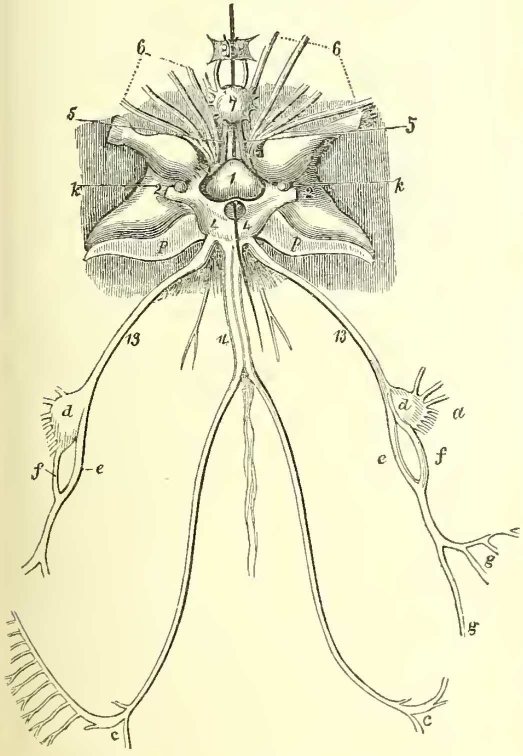
From the ganglions composing the posterior collar (4, 4) arise numerous nerves of a flattened form, (13, 13,) which pass in a radiated manner to the inner sides of the shell-muscles

* These ganglions I believe, from subsequent examination, to have been also connected with a nervous twig from the fleshy mass of the mouth, derived from the supra-œsophageal ganglion.

which they perforate, but there are no columns prolonged backwards from the lateral parts of the brain to form pallial ganglia as in the higher Cephalopods; the structure and functions of the cloak to which these ganglia are subservient, not being enjoyed by the shell-clad Nautilus. The nerves corresponding to the large visceral nerves of the Dibranchiates are, however, proportionally developed; for in the organs of plastic life the Nautilus is upon an equality with its naked congeners. These nerves, which combine the functions of the sympathetic and par vagum, consist of a large pair derived from the lower part of the posterior œsophageal collar, and extending backwards on each side of the vena cava; and of smaller twigs (17) coming off between the origins of the preceding nerves, and forming a plexus upon the parietes of the vein. The larger chords swell into ganglions at the termination of the vena cava, (16, 16,) and send off ramifications to the branchiæ, (15, 15,) the contents of the pericardium, and the viscera of digestion and generation.

In the Dibranchiate Cephalopods which possess instruments for varied and active locomotion, where the visual organ is of large size, and attains a complexity of structure equal to that of the Vertebrate animals, where a distinct acoustic organ is developed, and where the whole surface of the body is the seat of sensibility, the centre of nervous impression and volition is proportionally developed, and exhibits the highest conditions which the brain presents in the Invertebrate series of animals.

Fig. 232.



Nervous system of the Cuttle-fish.

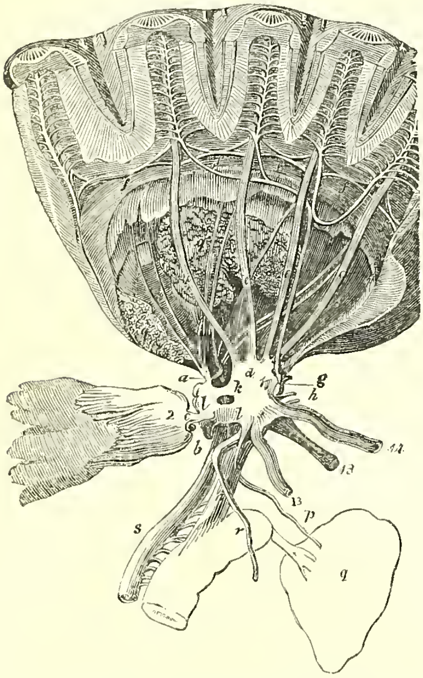
Except in some of the smaller species, as the Sepiola, in which the surrounding substance still retains the consistency of a membrane, the brain, together with the anterior and posterior œsophageal collars, is entirely surrounded by a thick cartilage. The portion of œsophagus which is thus enclosed is separated from the surrounding medullary matter by a thin layer of softer substance. The cerebral cavity is larger than the brain itself, and the intervening space is filled with a gelatinous fluid. In the Cuttle-fish the supra-œsophageal mass is transversely shortened, as compared with the Nautilus, and supports a smooth, rounded, heart-shaped medullary mass, slightly divided into two lateral lobes by a mesial longitudinal furrow (1, *fig.* 232); from the lower and lateral parts of this body proceed the broad bands of cerebral substance which afterwards dilate into the large reniform optic ganglions (2, 2); upon each of these bands is placed a small spherical medullary body (*k, k*). These bodies, which we first discovered in the *Sepia*, we have since ascertained to exist in *Loligo*.

From the anterior apices of the cerebral lobes small nerves are continued, which almost immediately dilate into a round flattened ganglion (*a, fig.* 233); this is closely applied to the back part of the fleshy mass of the mouth above the pharynx; it sends off nerves to the oral apparatus (*i, i, fig.* 233), and two filaments descend and form a pair of small closely approximated ganglions (8, 8, *fig.* 232) below the mouth, analogous to the labial ganglions of the Nautilus.

From the inferior, lateral, and anterior parts of the brain two large chords (*k, fig.* 233) descend, and unite and dilate below the œsophagus to form the anterior subœsophageal ganglion, or *pes anserinus* of Cuvier, from which the nerves of the feet and tentacles arise. Two still larger bands (*l, fig.* 233) descend from the brain behind the preceding to form, by a similar enlargement and union, the posterior œsophageal ganglionic collar. From a comparison of these with the corresponding ganglions of the Nautilus, it will be seen that by their approximation in the transverse direction the distinction of the ganglions at the lower part of the collar is lost; and a corresponding approximation in the antero-posterior direction, being accompanied by an additional accumulation of nervous substance, has produced a blending together of the four ganglions into one large continuous subœsophageal mass. The portions of this mass corresponding to the four ganglions and double œsophageal collar of the Nautilus, are notwithstanding indicated in a manner not to be mistaken, by the origins of the nerves which it sends off, and by the chords which bring it into communication with the cerebral mass above.

We shall now briefly mention the points in which the brain in other Dibranchiata differs from what we have described, after careful examination of this part in the Cuttle-fish. In the Poulp, the brain or supra-œsophageal mass is divided, according to Cuvier, into two parts, an anterior (*a*, *fig.* 233), which is of a flatter and squarer figure and of a whiter colour, compared by Cuvier to the cerebrum, but which seems to be the pharyngeal ganglion more closely approximated to the brain than in the Sepia: and a posterior globular mass (*b*), of a grey colour, which he compares to the cerebellum; the optic nerves (*c*) are much smaller than in the Cuttle-fish, and do not support the small spherical bodies which exist in the Cuttlefish and Calamary.

Fig. 233.



Brain and nerves of the Octopus vulgaris.

The brain of the Argonauta does not present a rounded form above, but when seen from this aspect, is composed, as in the *Octopus*, of an anterior white oblong band, flattened transversely, and of a posterior raised convex semilunar mass, which terminates behind in a semilunar border, the extremities of which are continued directly to form the posterior collar of the œsophagus.

The nerves of the arms proceed from the anterior and inferior subœsophageal ganglions (*d*, *fig.* 233), corresponding in number to the parts they supply, viz. eight in the *Octopoda* and ten in the *Decapoda*. But, according to Rathké, the *Loligopsis* offers an exception, the nerves of each lateral series of arms being continued for a short distance from the brain as a single pair. In the Poulp, the eight nerves (*e*, *e*, *fig.* 233) glide along the inner surface of the basis of the feet, which they penetrate respectively, running with the great artery in their substance, and forming, as Cuvier has described, a series of closely approximated ganglions, corresponding to each pair of suckers, and sending off radiated filaments. In the Genus *Eledone*, where the arms are narrower, and the suckers are arranged in a single series, the ganglia are relatively smaller.

In the peduncles of the *Decapoda* the nerves are continued of a simple structure as far as the acetabuliferous extremities, where they become enlarged and gangliated.

Before forming the ganglionic enlargements in the ordinary arms, each brachial nerve gives off two large chords, one to each side, which traverse the fleshy substance of the base of the feet to join the two corresponding branches of the contiguous arms; the eight nerves are thus associated by a nervous circle (*f*, *f*, *fig.* 233), which subdivides into two, and forms a small loop at each chord.

Behind the origin of the brachial nerves, the large infundibular nerves, a single pair (*g*, *fig.* 233), are given off. The small acoustic nerves (*h*) arise below and behind the nerves of the funnel, from the nervous substance that effects, as it were, the junction of the two œsophageal collars below. Next arise the large visceral nerves (14, *fig.* 232, 233), which, after distributing filaments to the muscles of the neck, descend parallel and close to one another behind the vena cava, give off from their inner sides the small filaments which constitute the plexus upon the vein; they then diverge from each other towards the root of each gill, where they divide into three principal branches: one of these dilates into an elongated ganglion (*c*, *fig.* 232), and enters the fleshy stem of the branchia; the second descends to the bottom of the sac; the third passes to the middle heart. The plexus previously formed upon the vena cava receives additional filaments from the two latter branches; and a large sympathetic ganglion is formed, which is attached to the parietes of the stomach, near the pyloric orifice.*

The most important and interesting nerves are the two large ones, (13, 13, *figs.* 232, 233,) which arise from the posterior and lateral surface of the subœsophageal mass, and extend outwards, downwards, and backwards, perforating the shell muscles, and forming upon the inner parietes of the mantle the large stellated ganglion (*d*, *d*, *fig.* 232), from which the nerves of the mantle are derived. In the Octopoda the

* See Brandt Medicin. Zoolog. a. a. O. S. p. 309, tab. xxxii. fig. 23, who first described this ganglion in the Sepia, and Jacob's figures of the Anatomy of the Octopus Vulgaris, pl. xv. fig. 7; pl. xiii. figs. 2 & 3, in Ferussac's Monograph on Cephalopods, fol.

nerve terminates in this ganglion, (*v, v, fig.* 226,) from which about twenty branches radiate to the mantle; but in the Decapoda, in which lateral fins are superadded to the trunk, it previously divides into two large branches. Of these the external alone produces the ganglion from which the sensitive nerves are distributed in a radiated manner, as in the Poulp; the other division (*e, fig.* 232), after having been joined by a branch (*f*) from the ganglion, pierces the fleshy substance of the mantle, and ends in a diverging series of twigs appropriated to the muscles of the fin (*g*). In proportion as the trunk of the Cephalopod is elongated, these branches become more parallel in their course, and dorsal in their position.

The anterior part of the mantle is supplied by small nerves, having a distinct origin from the posterior subœsophageal mass, above the great moto-sensitive chords.

With respect to the parts of the central axis of the nervous system of the Vertebrata which are represented by the structures above described, we may reasonably infer from the fact that the supraœsophageal mass in the Dibranchiate Cephalopods, especially the posterior division, is principally in communication with, and owes its superior development chiefly in relation to the complex organs of vision, that it is analogous to the optic lobes or bigeminal bodies. For if it be regarded, as Cuvier supposes, as the cerebellum of the vertebrate brain, we have then to reconcile the anomaly of this part being the seat of origin of the optic nerves. The constancy, again, of the optic lobes in the vertebrate series, and their priority of development to the cerebellum, leads naturally to the expectation that these would form part of such a brain as the highest invertebrate animal is endowed with. The smaller portion of the brain of the Poulp anterior to the optic lobes appears to represent an olfactory lobe. With respect to the inferior œsophageal mass, as it gives origin to the auditory and respiratory nerves, and those two large moto-sensitive columns, which evidently represent, by their structure and position, the spinal cord of the *Vertebrata*, we consider it as fulfilling the function of the medulla oblongata, and to be the part of the nervous centre which is most intimately connected with the vital energies of the animal.*

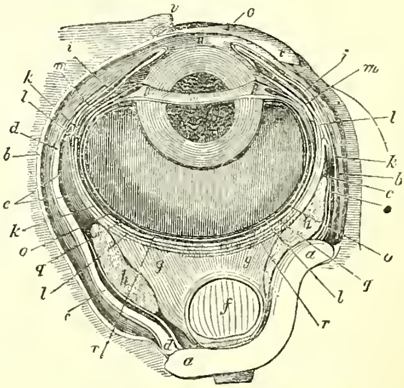
Organs of Sense.—The Cephalopodous class is the only one in the Invertebrate series in which distinct organs of sight, hearing, smell, and taste, have been detected, although the enjoyment of these senses is evidently by no means limited to this class. Considerable differences, however, present themselves in the relative complexity, and even as to the existence of the different Organs of Sense in the two orders of Cephalopods: thus, of the senses which relate to distant objects, the Organ of Hearing appears to be wanting in the Nautilus, and the Organ of Vision is comparatively imperfect, while those which take cognizance of proximate objects are more distinctly and extensively developed.

Organ of Sight.—In the Nautilus the eyes are supported on short pedicles which project outwardly from the sides of the head. They are of a spherical form, slightly flattened anteriorly; are large as compared with the pedunculated eyes of Gasteropods, but are of small size as compared with the complex visual organs of the Dibranchiates. They presented, in Mr. Bennett's specimen, the simplest condition of an organ of vision, consisting only of a darkened globular cavity or *camera obscura*, into which light was admitted by a single orifice, and a nerve expanded at the opposite side to receive the impression; the mechanism for regulating the admission of the impinging rays was wanting, and every trace of that which modifies their direction had disappeared. The form of the eye was maintained by a tough unyielding sclerotic coat (*k, fig.* 231), which became thinner towards the anterior part of the eye, where it was perforated by a circular aperture less than a line in diameter (*m*). The nerves continued from the small oval optic ganglion (2) expand, and immediately line the sclerotic as far as the middle of the globe, forming a strong reticulate retina (*o*), which, together with the rest of the cavity, is lined by a black pigment (*n*). There was no appearance of vitreous humour or crystalline lens; but both parts would no doubt be found to exist in the recent state.

In the *Dibranchiata* the eyes are sessile, but in some species project beyond the surface of the head more than in others; their complicated structure is truly one of the most remarkable features of the organization of this singular class.

The eyeball in the Cuttle-fish is inclosed in a capsule consisting posteriorly of a thick cartilage (*a, a, fig.* 234), in its lateral circumference

Fig. 234.



Section of the Eye of the Cuttle-fish.

of a strong white fibrous membrane (*b, b*), and anteriorly of the cornea (*o*).

The whole of the inner surface of the capsule is lined by a thin serous membrane, as far

* See vol. iii. pt. 1, p. 187. Physiological Catalogue of the Museum of the Royal College of Surgeons, 4to. 1835.

as the margin of the thick posterior cartilaginous orbit, to which it is attached, and is thence reflected forwards (*c*, *c*) upon the muscles of the eye-ball, also upon the long narrow anterior and inferior ocular cartilage (*d*, *d*), and upon the exterior fibrous layer of the sclerotica; it is reflected inwards over the anterior thickened margin of the sclerotica, where the large anterior aperture of that membrane remains unclosed by the cornea, and consequently passes along its inner surface like the membrane of the aqueous humour; it seems to us, however, not to pass over the anterior part of the capsule of the crystalline lens, but into the groove (*p*, *p*) which divides that body into two parts. The serous layer above described cannot be detached from the cornea, but ceases to be demonstrable as a distinct membrane where the external fibrous coat is attached to the cornea. The space between the eye-ball and its capsule, which is thus circumscribed, is filled with a watery fluid, which is most abundant in the Calamaries. The cornea is separated by the same fluid from the eye-ball; but its tension and slightly convex figure is maintained by it, as by the aqueous humour in the eye of the vertebrate animal. The motions of the eye-ball are facilitated by the secretion of the serous sac, as the movements of the heart in the pericardium, and in other instances in which serous membranes are developed.

The membrane, of which we have just described the reflections and extent, is regarded by Cuvier as analogous to the tunica conjunctiva, but a difficulty arises in this mode of considering it, in consequence of the position of the cornea (*o*), which, in its structure and connection with the integument, bears a close analogy to the cornea in Fishes. The characteristic difference which the cornea presents in the latter class, as compared with that of the Cephalopoda, is its adhesion to the margins of the anterior aperture of the sclerotica, by which the anterior chamber of the eye is limited to a very small space; while in the *Sepia* it would seem as if the membrane circumscribing the anterior chamber had over-passed its usual bounds in consequence of the absence of any such adhesion between the cornea and sclerotica. When we consider the nature of the membrane in question, and the relations of the fluid it secretes to the cornea and crystalline, should we not be justified in considering it, notwithstanding its excessive development, as analogous rather to the membrane of the aqueous humour, than to the conjunctiva, the ratio of the development of which is as that of the eye-lids or folds of membrane external to the cornea, and of which we have only a slight rudiment in the *Sepia? (v.)*

The space between the cartilaginous orbit and the posterior part of the eye is circumscribed by a membrane (*e*, *e*) which has the character rather of a condensed layer of cellular tissue than of a true serous membrane. In this space is contained the optic ganglion (*f*), its filaments (*g*), and the surrounding soft white substance (*h*), by some considered of an adipose, by others of a glandular nature. This cavity is proportionally larger in the *Octopus* than in the *Sepia*.

The eye-ball of the Cuttle-fish is an irregular spheroid, flattened in the direction of its axis. The vertical diameter is less than the horizontal, but both exceed the diameter of the axis. The eye-ball is remarkable in all the *Dibranchiata* for its considerable development as compared with the size of the body; it is proportionally largest in the Calamaries, and smallest in the Octopods.

The exterior membrane covering the anterior part of the eye-ball (*i*) receives the insertions of the muscles of the eye, and seems as if it were formed by their aponeurotic expansions; it lies immediately beneath the reflected layer of the serous covering, is of a soft texture, and has a pinkish colour with a glistening silver lustre; in the Poulp it is spotted like the skin. The entire eye-ball is surrounded by a second layer of membrane (*k*, *k*), having a similar texture and appearance; these are analogous to the exterior or fibrous layers of the sclerotica in the eyes of Fishes. We next find a cartilaginous layer (*l*, *l*) corresponding to the internal cartilaginous sclerotica of the Plagiostomous Fishes. This coat is very thin, and almost membranous posteriorly, where the fibrils of the optic ganglion penetrate it, and where it presents a cribriform surface of considerable extent, in which it may be observed that the orifices of the sieve are of considerable size, and not very close together. Anterior to the cribriform surface the cartilaginous sclerotica increases in thickness, but more so on the lower than the upper side of the eye, and about the middle of the eye-ball it terminates in a slightly thickened margin. A layer of fibrous membrane (*m*, *m*) is continued from this margin, along with the external fibrous layer (*l*), and assists in forming the soft thick anterior part of the sclerotica, which forms the circumference of the pupillary aperture (*n*), or that by which light is admitted to the cavity of the eye. The superior part of this aperture is encroached upon by a bilobed curtain-like process, which we have observed to present a semi-transparent texture in the eyes of some Cuttle-fishes, as if it were an abortive formation of a sclerotic cornea: in position it resembles the curtain-like process depending from the iris of the Ray.

The inner surface of that part of the sclerotica which lies anterior to the lens is lined with a dark pigment.

The tunic which immediately lines the cartilaginous sclerotic is not, as in Fishes, a membrana argentea, or a vascular choroid, but consists of an expansion of the nervous fibres which are given off from the optic ganglion, connected together by a vascular and cellular tissue (*o*, *o*). The ganglion does not resolve itself into these fibres uniformly from the circumference to the centre, but sends them off from its exterior surface only, so that, on making a section of the part, the centre of the ganglion presents a homogeneous pulpy texture, separated by a distinct external layer from the origins of the fibrils, as in the figure, *f*.

The fibres, after perforating the cartilaginous sclerotica, and expanding into the post-pigmental retina, extend towards the groove of the crystalline, in a direction chiefly parallel to one another, the tunic formed by them becoming thinner as they advance forwards; this is joined by a thin membrane, which extends from the anterior margin of the cartilaginous sclerotica, and forms, with that membrane, a ciliary plicated zone *(p, p,* where it is represented as left entire,) which penetrates the groove of the lens. The outer surface of this thick nervous tunic is fibrous and flocculent, and connected to the sclerotica by a fine cellular tissue: the anterior or internal surface is perfectly smooth.

This surface of the nervous tunic is covered by a tolerably consistent layer of a dark purple-brown pigment (*q*). Cuvier, who regards the preceding tunic as the only part analogous to the retina in the eye of the Cephalopods, expresses his surprise that this black layer is not an insurmountable obstacle to vision;* and different theories have been proposed to account for the singular position of the pigment on that supposition. In the eyes of different *Sepiæ* which we had immersed in alcohol preparatory to dissection, we have, however, invariably found between the pigment and the hyaloid coat a distinct layer of opaque white pulpy matter (*r*), of sufficient consistence to be detached in large flakes, and easily preserved and demonstrated in preparations. We confess, however, that we can discover no connection between this layer and the thick nervous expansion behind the pigment; but, nevertheless, we cannot but regard it as being composed of the fine pulpy matter of the optic nerve, and as constituting a true præ-pigmental retina.

The hyaloid coat, which is remarkably distinct in all the Cephalopods, completely separates the vitreous humour from the internal white layer above described. It is perfectly transparent, and, though thin, is strong. The vitreous humour does not lose its transparency when preserved in alcohol.

The crystalline lens is of large size, and is composed of two completely separated portions: the anterior moiety is the segment of a larger sphere, but forms the smaller part of the lens; the posterior is a segment of a smaller sphere, and forms the larger part of the lens. Two layers of transparent membrane are continued from the ciliary body between these segments. Each of the segments is composed, as in the lens of higher animals, of concentric laminæ, which become denser towards the centre, where the nucleus resists further unravelling of its structure. It is of a brown colour, and preserves its transparency in alcohol. The laminæ are composed of denticulated fibres; but the minute description of their texture and arrangement will be given in another place.

The white substance *(h)* which surrounds the optic ganglion is divided into lobes, but exhibits no distinguishable secerning structure; the bloodvessels of the eye ramify between these masses; the smaller twigs accompany the nervous fibrils; the larger ones pass forwards to the anterior soft margin of the sclerotica. We regard this substance as analogous to the so-called choroid gland in the eyes of Fishes. Cuvier assigns to it the function of defending the nervous ganglion and fibres from surrounding pressure; and this is most probably the true final intention of the substance, since it intervenes between the ganglion and the muscles of the eye-ball.

Of these we find three straight muscles and one oblique. The *inferior rectus* of each eye arises from a small transverse tendon which adheres to the inferior and anterior border of the cranial cartilage, to which it runs parallel, and is attached at its two extremities to the muscles above mentioned, and also to the base or root of the anterior elongated cartilaginous orbital plate.

A second straight muscle arises from the posterior margin of the elongated cartilage above mentioned; its fibres run parallel to those of the preceding, and are inserted into the external sclerotica. Both these muscles are thin, broad, and fleshy.

The oblique muscle arises from the inferior and posterior margin of the external orbital cartilage, and expands, as it proceeds outwards and forwards, to terminate in the external membranous sclerotic. These muscles are readily exposed by dissecting away the orbital capsule from the under part of the eye-ball.

A short and strong superior rectus, the tendon of which is continuous with that of the opposite side, is inserted into the upper part of the sclerotic.

A few observations remain to be made on the structures defending the anterior part of the eyeball. The cornea of the Cuttle-fish is apparently entire; it is thickest at its superior margin *(t)*, where it is implanted in a groove of the integument; it becomes gradually thinner towards the lower margin, where it is overlapped by the rudimental eyelid *(v)*. This consists of a narrow semilunar fold of integument, the concavity of which is directed upwards and a little backwards.

In the small Cephalopod which Captain Ross discovered in the Arctic Ocean, and which has been named after that distinguished and scientific navigator,* the cornea is defended by a continuous circular fold of integument, which can be completely closed by an orbicular sphincter in front of the eye, a structure which is probably required in this species in order to protect the cornea against the spiculæ of ice with which its native seas abound, especially in the summer or thawing season. In the Calamary, on the other hand, there is no tegumentary fold. Upon carefully inspecting the cornea of the Cuttle-fish, a minute foramen will be seen near the inner or anterior margin of the cornea, covered by the upper extremity of the fold of integument. The aperture leads ob-

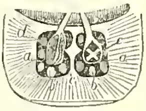
* "On ne conçoit pas comment elle n'est pas un obstacle insurmontable à la vision."—*Mém. sur le Poulpe*, p. 39.

* See Appendix to Sir John Ross's Voyage, 4to. p. xii. pl. B. C.

liquely downwards and backwards, and if air be blown or fluid injected through it, the large cavity surrounding the anterior part of the eye-ball will be distended, and the cornea rendered convex. In the Poulp the corresponding aperture (*o*, *fig.* 216) is somewhat larger, and situated more in the axis of vision: its inferior and posterior margin is extended beneath the opposite margin, so as to form a semi-transparent curtain behind the external opening. In the common Calamary and the Onychoteuthis the corneal perforation is still larger, vertically oblong, and through it the capsule of the crystalline lens, which projects through the sclerotic aperture, is immediately exposed to the external medium.

Organ of Hearing.—This organ has hitherto been found only in the Dibranchiate division of the Cephalopods. It consists, as in the Cyclostomous or lower organized cartilaginous Fishes, of an acoustic vestibule, containing a limpid fluid and a calcareous body or otolithe suspended in a delicate sacculus to the filaments of the auditory nerve, but without the semicircular canals, cochlea, or other parts which progressively complicate the Organ of Hearing in the higher animals.

Fig. 235.



Organ of Hearing, Cuttle-fish.

The vestibular cavities (*a*, *a*, *fig.* 235) are situated, not at the sides, but at the base of the cranium in that thick and dense part of the cartilage which supports the sub-œsophageal cerebral masses. In the Cuttle-fish the cavities are of a sub-quadrate form, separated only by a thin septum (*c*); and they are every where closed, except at the entrance of the nerve. From their inner surfaces project several obtuse moderately elongated processes (*b*, *b*, *fig.* 235), of a soft elastic texture, which support the central sacculus (*d*) and otolithe (*e*), and doubtless serve to convey to it the vibrations which affect the body generally. The sinuosities in the intervals of these processes seem to be the first rudiments of those which in the higher classes are extended in the form of canals and spiral chambers within the substance of the dense nidus of the labyrinth. The otolithe in the *Sepia officinalis* is of an irregular flattened quadrangular figure, with two of the angles produced so as somewhat to resemble the human *incus*: the surface next the parietes of the sacculus is convex and smooth, the opposite one concave and broken: it is white and transparent. (In *fig.*235, the otolithe is seen as exposed in the sacculus on the right side.)

In the *Octopus vulgaris* the vestibules are nearly spherical, and their parietes are smooth; the otolithes are of an hemispherical figure attached to the dorsal part of the membranous sac, of a white colour on the adherent surface, and yellow on the opposite side: the rest of the sacculus is filled with a transparent gelatinous fluid. The auditory nerve divides into three branches, which spread over the sacculus, and convey to the sensorium the vibrations which affect the otolithe and its sac.

In the *Eledone cirrosa* the otolithe is shaped like the shell of a limpet, with the apex rounded and curved backwards; of a pink colour on the sides, but of a white semitransparent texture internally.

The otolithes in all the Dibranchiates effervesce with acids, like other substances composed of carbonate of lime; and in the Poulp, Eledone, and all the Decapods except the Cuttle-fish, they are the only earthy substances which enter into the organization of these animals.

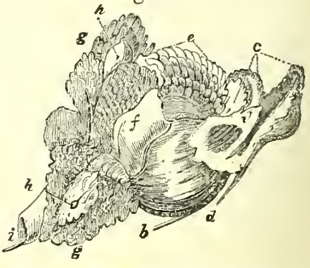
Organ of Smell.—The sense of smell has been attributed to the Cephalopods by all naturalists who have written on their habits; from Aristotle,—who mentions the strong-scented herbs which the Greek fishermen attached in his day to their baits, in order to prevent their being destroyed by the Mollia,—down to Cuvier, who expressly asserts that they are attracted by the odour of different substances. But no organ expressly appropriated to the exercise of the olfactory sense has been determined in the Dibranchiate Cephalopods.

In dissecting the Nautilus Pompilius, our attention was directed to a series of soft membranous laminæ (*h*, *fig.* 231) compactly arranged in a longitudinal direction, and forming a circular body very closely resembling the laminated olfactory organ in Fish. The position of these laminæ, as well as their form and arrangement, supported the belief that they exercised the functions of an olfactory organ; being situated just before the entrance of the mouth, between the internal labial processes: nerves were also traced to them from the inferior labial ganglions. From analogy we are inclined to suppose that the external lips in the Dibranchiate order may be the seat of the olfactory sense.

Organ of Taste.—From the elaborate structure which the tongue displays in both orders of Cephalopods, there can be no doubt but that these destructive creatures fully relish the prey that they devour, and, in correspondence to their particular tastes, are led to select those species the limitation of whose increase is assigned to their charge.

The anterior soft papillose lobes of the tongue of the Nautilus are shewn in the subjoined figure (*fig.* 236), in which they are

Fig. 236.



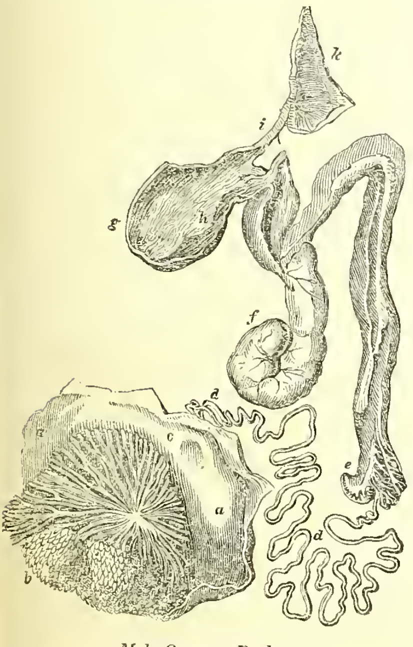
denoted by the letter *c*; *e* indicates the middle spiny plate, *f* the posterior coarser papillose surface, and *g* the faucial folds. The nerves of this part are derived from the brain itself, or supra-œsophageal mass.

Organ of Touch.—With respect to the sense of touch, the exposed part of the integument of the Nautilus presents numerous papillary eminences; and several of the naked Cephalopods are remarkable for the irregular surface of the skin, which seems designed to increase its natural sensibility. Thus, in the *Cranchia scabra*, flattened processes terminating in numerous pointed denticulations, project from the surface of the mantle; in the *Sepia papillata* the integument is beset with branched papillæ; in *Sepia mammillata* with more simple obtuse eminences; in *Sepia tuberculata*, with tubercles; in *Octopus aculeatus*, with pointed tubercles, &c. That these projections serve to warn the creature of the nature of the surfaces which come in contact with its body is highly probable; and it is not at all uncommon to find in those species, which have smooth skins over the body generally, that there are tubercles in the immediate neighbourhood of the eyes, as in the *Octopus vulgaris, Octopus Lichtenaultii, Octopus Westerniensis*, &c.

In the Nautilus, the more exposed pedunculate eyes are expressly provided with retractile sensitive tentacles on each side, as has been already mentioned.

With respect to the organs destined for the active exercise of touch or exploration, we must suppose that the numerous tentacles with which the Nautilus is so remarkably provided, from the softness of their texture, their annulated surface, and liberal supply of nerves, serve in this capacity as well as instruments of prehension and locomotion. The less numerous but more highly developed arms of

Fig. 237.



Male Organs, Poulp.

the Dibranchiates doubtless exercise the same faculty, especially at their attenuated flexile extremities.

The internal fringed circular lip surrounding the mandibles, in both orders of Cephalopods, presents another example of the dermal covering so disposed as to be the seat of delicate sensation.

Generative System.—The individuals of the present class are, as before stated, of distinct sexes, which in the Dibranchiate order are recognizable by diversity of size, external form, colour and shape of the internal rudimental shell. In the common Calamary, for example, the gladius of the male is one-fourth shorter, but broader than that of the female.

As only the female organs are known in the Tetrabranchiate order, we are limited in the description of the male parts, to those which exist in the Dibranchiate Cephalopods; but from the close resemblance subsisting in the two orders in the form of the organs of the female sex, little difference can be expected to exist in the structure of the male apparatus.

In the Poulp the male organs consist of a testicle, a vas deferens, a kind of vesicula seminalis, a gland compared by Cuvier to the prostate, the sac containing the moveable filaments which Needham's description rendered so celebrated, and lastly the penis.

The testicle is situated at the bottom of the visceral sac, and is composed of a membranous pouch (*a*, *fig.* 237), to one part of the inner surface of which are attached a number of branched elongated glandular filaments (*b*), which swell at the breeding season, and discharge an opake white fecundating fluid into the sac. From this cavity the fluid escapes by the orifice (*c*), and passes into the vas deferens (*d*). This is a narrow tube, indefinitely convoluted upon itself; it opens into another larger canal (*e*), the interior of which is divided by ridges and incomplete septa; its texture seems to be muscular, so that it probably serves by its contractions to eject the fluid carried into it by the vas deferens. From the vesicula seminalis the semen next traverses the extremity of an oblong gland (*f*), which is of a compact granular structure, and, like the prostatic or Cowperian glands, contributes some necessary secretion to the fecundating fluid.

Next follows the muscular pouch (*g*) containing the filaments or animalcules of Needham (*h*). When first exposed, they present the appearance of white filaments, from six to eight lines in length, packed closely and regularly in parallel order, in three or four rows one above another, from the fundus to the aperture of the pouch; and they are kept in that position by a spiral fold of the membrane of the pouch, without, however, having the slightest adhesion to that part. For a long time after being removed from their position they continue to exhibit, when moistened, motions of inflection in different directions. A short and narrow canal (*i*) leads from the pouch to the root of the penis (*k*), which is a short pyramidal body, hollow within, and terminating by a small anterior aperture.

In the Sepiola the part corresponding to that called the *prostate* by Cuvier exists, but is relatively smaller, and the duct by which it communicates with and is appended to the vas deferens is relatively longer; the sac of the filaments is relatively larger, exceeding doubly the dimensions of the testis; the penis is much shorter.

In the Onychoteuthis the penis is merely grooved, as in the Pectinibranchiate Mollusks, not perforated, and such may be expected to be its structure in the Pearly Nautilus.

With respect to the act of impregnation in the Cephalopods, Aristotle gives two accounts. In the fifth book of the *Historia Animalium* it is stated that the Octopus, Sepia, and Calamary, all copulate in the same manner; the male and female having their heads turned towards one another, and their cephalic arms being so co-adapted as to adhere by the mutual apposition of the suckers. In this act the Poulps are described as seeking the bottom, while the Cuttles and Calamaries are stated to swim freely in the water, the individual of one sex moving forwards, the other backwards. Aristotle also observes that the ova are expelled by the funnel, which the Greeks called *physetera* (φυσητηρα), and some, he adds, assert that the coitus takes place through that part.

From the position of the oviduct at the base of the funnel, and the inclination of the penis to the same part, from the left side, the latter supposition derives some probability, especially with respect to the *Sepia* and *Sepioteuthis*, in which the penis is of large size, although true intromission is physically impossible in these, as in all other Cephalopods. There may, however, be an imperfect connexion, analogous to that of the Frog, Toad, &c. and it is worthy of remark that the differences in the situation where the *coitus* is said to take place, in Aristotle's remarkable account, corresponds with the modifications of the locomotive powers in the three genera treated of; it is only, for example, in the Sepia and Loligo that the individuals are provided with posterior fins for swimming forwards.

In the twelfth chapter of the sixth book of the *Historia Animalium*, where the generation of Fishes is treated of, the Stagyrite observes — ' When they (fishes) bring forth, the male following the female sprinkles the ova with his semen:—the same thing happens in the Malakia; for in the genus *Sepiæ*, where the female deposits the ova, the male follows and impregnates them : this possibly happens in like manner to other Malakia, but, hitherto, it has been observed in the Sepiæ alone.' It reflects, perhaps, little credit on modern Naturalists, that the knowledge of this part of the economy of the Cephalopods should remain in the same unsatisfactory and conjectural state as it was two thousand years ago.

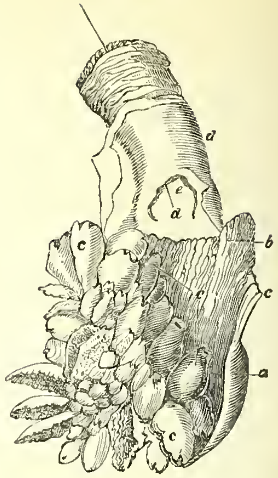
The female organs exhibit four principal types of structure in the Cephalopods.

The ovary is single in all.

In the *Nautilus* there is one oviduct, and one superadded glandular appendage.

In the *Sepia* and many others, there is also one oviduct, but there are two separated nidamental glandular laminated organs which open near its extremity.

Fig. 238.



Female Organs of the Nautilus.

In the *Loligo sagittata* there are two distinct oviducts, and two separate nidamental glands.

In the *Octopoda* there are two distinct oviducts, each of which, as in the Ray and Shark, passes through a glandular organ in its course towards the base of the funnel, but there are no detached glands.

In the Nautilus the ovary (*a*, *fig.* 238) is situated, as in the higher Cephalopods, at the posterior part of the visceral sac, in a distinct compartment of the peritoneum; and the gizzard, which here descends lower down than in the *Dibranchiata*, is lodged by its side. The ovary is of an oblong compressed form, and in the specimen dissected, measured one inch and a half in length and one inch in breadth. It consists of a simple undivided hollow sac, with thick and apparently glandular parietes, rugose on the inner surface, and having an anterior aperture (*b*) with puckered margins, directed forwards.

The ovisacs (*c*, *c*) are numerous, of an oval form, and attached by one extremity, in a linear series, along the internal surface of the ovarian sac on the dorsal aspect. In the specimen here described they were collapsed, and had evidently recently discharged their ova; the rent orifices by which these had escaped were still patent and conspicuous. The tunics of the ovisacs, as in the *Dibranchiata*, were glandular, but the internal plicæ did not present the reticulate disposition characteristic of the corresponding parts in the *Sepia*, &c. The exterior thin membrane (*d*) of the ovary is continued forwards to form the oviduct: the thick glandular tunics of this canal commence by a distinct aperture (*e*), just above the outlet of the ovary, and continue increasing in thickness to the extremity of the oviduct, where the glandular membrane is disposed in numerous deep and close-set folds: the length of the glandular part of the oviduct is one inch; its termination is at the base of the funnel close to the anus, and immediately behind an accessory glandular apparatus.

This body is analogous to the laminated ovarian gland of the Pectinibranchiate Testacea, and, as in them, forms no part of the oviduct; but in the Nautilus it is extended in the transverse direction, and composed of two lateral convex symmetrical masses, resembling the corresponding separate symmetrical glands in the *Decapoda*, but which are here united by a third middle transverse series of laminæ. All the laminæ are deep, pectinated, and close-set, and are supplied by a large artery. The lateral groups form conspicuous projections on the external surface of the ventral aspect of the Nautilus, and are covered internally by a layer of thin tough membrane; the middle laminæ are exposed.

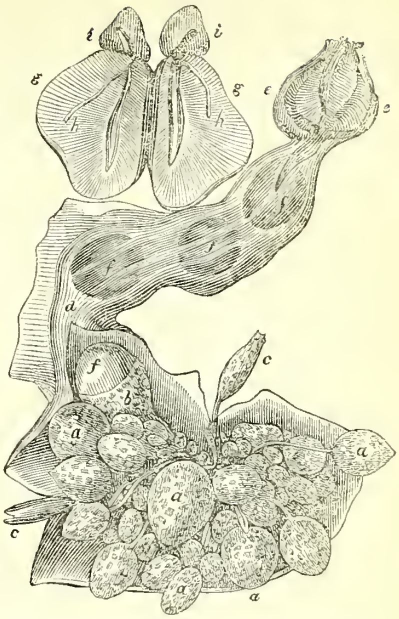
The female organs of the Dibranchiate Cephalopods present different structures, as before observed, in the Decapodous and Octopodous tribes. In the former the oviduct or oviducts have laminated glandular terminations, near to which are placed two detached nidamental glands: in the latter there are always two distinct oviducts which pass through laminated glands, but there are no detached superadded glandular organs.

The Sepia, among the Decapodous Cephalopods, manifests in its generative, as in its prehensory and testaceous organs, a near affinity to the Tetrabranchiate order, while the form of the female apparatus in the Octopods more closely corresponds, on the other hand, with the same parts in the Oviparous Cartilaginous Fishes. The ovarium in both tribes is a single organ, situated at the bottom of the pallial sac, and consisting of a capsule and ovisacs diversely attached to its internal surface.

The ovisacs are proportionally larger in the Decapods than in the Octopods. In the Cuttle-fish they are extremely numerous, and are appended by long and slender pedicles to a longitudinal fold of membrane extending into the ovarian cavity, from the dorsal aspect of the sac. The plicæ of the internal glandular surface of the ovisacs or calyces are disposed in a reticulate manner, forming corresponding light-coloured opake lines on the external surface, which, being contrasted against the dark-brown tint of the contained ovum shining through the transparent areolar space, occasions the beautiful and characteristic exterior reticulate markings of the undischarged ovisacs.

In the Genus *Rossia*, from which the subjoined illustration of the Decapodous type of the female organs is taken (*fig.* 239), the ovisacs have the same structure and mode of attachment as in *Sepia*, but they are relatively of double the size and fewer in number. In the specimen which we dissected, we found the greater part of the ovisacs containing the ovum in various stages of development, as at *a*, *a*. One was in the act of shedding the ovum, as at *b*, *f*; others were

Fig. 239.



Female generative Organs, Rossia palpebrosa. (*Natural size.*)

discharged, collapsed, and shrivelled, and in progress of absorption, as at *c*, *c*. The parietes of the ovarium consist of a thin and almost transparent membrane, which is continued forwards to form the oviduct (*d*, *d*). This canal commences in the Cuttle-fish by a round aperture, about a third of an inch in diameter, immediately beyond which it dilates, and continues forwards of the same thin and membranous structure to within an inch of its extremity, where, as in the Nautilus, its parietes are suddenly thickened by the development of a number of broad, close-set, glandular laminæ. The chief difference between the Sepia and the Nautilus obtains in the greater extent of the membranous part* of the oviduct in the former.

In the *Rossia* the oviduct (*d*) differs only in greater relative width: the terminal gland (*e*) is composed of two lateral semioval groups of transverse glandular lamellæ, each group being divided by a middle longitudinal groove; the oviduct was contracted immediately before opening into the interspace of the glands, and a deep but narrow groove, which is probably dilated during the passage of the ova, was continued between the two groups of lamellæ to the termination of the oviduct. This was situated towards the left side and behind the orifices of the nidamental glands.

The female organs of the *Sepiola* present the

* In the original description of the Nautilus, this membranous part of the oviduct was regarded, from its brief extent, and the sudden commencement of the glandular tunic, as a connecting process of the peritoneum; it was accurately represented, however, in the figure, (*pl.* viii. *fig.* 9.)

same structure as in *Sepia* and *Rossia*, but the single oviduct is relatively wider than in the latter genus, the ova being of remarkably large size. In the Calamary the ovary is more elongated, and the ovisacs and ova are relatively smaller than in any of the above genera. In the common species (*Loligo vulgaris*) the oviduct is single, but narrower, and more elongated than in the Sepia, and, like the vas deferens in the male, it is disposed in convolutions; its terminal gland is relatively larger and longer; and the detached nidamental glands are correspondingly restricted to a smaller development.

In the great Sagittated Calamary, which is not uncommon on our north-western shores, we found in a large specimen taken before the beginning of the breeding season, that the oviducts commenced by separate apertures about two inches apart from the anterior surface of the great ovarian bag, and were immediately disposed in sixteen short transverse folds, beyond which they continued straight to the terminal ovarian gland. The whole length of each oviduct was two inches; the convoluted portion occupying one inch; the straight and glandular parts each half an inch. Monro, in his anatomy of this species of *Loligo*, conjectured that the glandular appendages of the biliary ducts, of which he gave a figure, were the ova: of the oviducts and nidamental glands he had no knowledge. The latter parts are situated external to the terminations of the oviducts; they are of a narrow, elongated, flattened form, about one inch and a half in length, with a wide cavity for moulding the secretion of the two lateral series of glandular laminæ.

The ova which are contained in the membranous part of the oviduct of the Sepia, consist of a deep yellow vitellus, inclosed, first, in a very delicate vitelline membrane, and, externally, in a thin, smooth, shining, easily lacerable, cortical tunic, or chorion. We have generally found them in great numbers, squeezed together in a mass, so that few retained their true form.

The external tunic of the ova in *Rossia* is stronger than in *Sepia*, and the form of the ovum, which is elliptical, is consequently better preserved: the oviduct, in the specimen dissected by us, contained several ova detached from one another, in progress of exclusion, as represented in the figure at *f*, *f*. The ova in *Sepiola*, as in the two preceding genera, are devoid of any external reticulate markings, which belong only to the ovisac or formative calyx.

The delicate ova are defended by additional layers of a horny substance deposited on their external surface by the terminal gland, which may be compared to the shell-secreting segment of the oviduct in the Fowl. When the ova quit the oviduct, they are connected together by, and probably receive a further covering from, the secretion of the two large superadded glandular bodies (*g*, *g*, *fig.* 239), the wide ducts of which converge and open close to the termination of the oviduct.

These bodies, in the Cuttle-fish, Sepiola, and Rossia, are of a pyriform shape with the apices, converging and turned forwards; of large size, especially at the reproductive season, situated on the ventral aspect of the abdomen, but not attached, as in the Nautilus and inferior Mollusks, to the mantle. They are each composed of a double series of transverse, parallel, close-set semi-oval laminæ, the straight margins of which are free and turned towards each other along the middle line of the gland. When the gland is laid open, an impacted layer of soft adhesive secreted substance is found occupying the interspace of the two series of laminæ; in which, in *Rossia*, it is evidently moulded into a filamentary form, whence it escapes by the anterior orifice above mentioned. (See *h*, *h*, *fig.* 239.)

The laminæ are attached by their convex margins to the capsule of the gland, which is thin, and probably contractile; it is completely closed at every part save the anterior outlet, forming a shut sac posteriorly, and having no communication with the oviduct or oviducts, for which these glands have sometimes been mistaken.*

In the Cuttle-fish the extremities of the ovarian glands rest upon a soft parenchymatous body of a bright orange colour: the corresponding part is rose-red in the *Sepiola*, and of a bright colour in all the congeneric species. In the *Sepia* this body is trilobate, consisting of two lateral slightly compressed conical portions, whose obtuse apices are directed forwards, and a smaller middle portion connecting the lateral ones at their posterior and internal angles. The dorsal surface of the lateral lobes is flattened, the opposite side excavated to receive the superincumbent extremities of the ovarian glands. To these the substance in question is closely attached by a tough connecting membrane, but has no correspondency of structure nor any excretory outlet. Its texture is dense and granular, with minute cells, the largest of which are in the centre of the body, and are filled with a yellowish brown caseous substance. In *Sepiola* the corresponding body is single, and is similarly attached to the anterior extremities of the two nidamental glands. In the

* In the description of the anatomy of the *Loligopsis* by Dr. Grant, contained in the first volume of the Zoological Transactions, it is stated that "the usual large glands of the oviducts appear to be wanting," p. 26; whence we are led to conclude that the oviducts are double in that genus as in the Octopods. Rathke, however, describes the oviduct as being single, and states that it is continued downwards to terminate at an aperture situated on the ventral surface of the hinder extremity of the body. This is so singular a deviation from the Cephalopodous type of structure, and makes so important a step towards the Vertebrate Organization, that we have selected the figure (*fig.* 223) in which the learned author above quoted illustrates this part of his observations on *Loligopsis*, where 14 represents the ovary, 15 the oviduct, and 16 its posterior terminal aperture. Further dissection of this remarkable genus is, however, evidently required, in order to reconcile the discrepancies in the accounts of the anatomy of these animals which have hitherto been published, both as to the generative system and in reference to other important structures.

Loligines and in *Rossia* it is double; each portion (*i, i, fig.* 239) in the latter genus is attached by cellular tissue to the anterior part of its corresponding nidamental gland, and is excavated by a deep groove close to the aperture of tbe gland: from this structure and their position it would appear that they assisted in moulding the nidamentum, and, perhaps, in applying it to the ova. Considering the texture of these singular bodies, their ordinarily bright colour, and their relative position to the generative apparatus, we believe ourselves justified in regarding them as the analogues of the *glandulæ succenturiatæ* or 'supra-renal bodies' of the Vertebrate animals.

In the Octopodous Dibranchiates the ovary is a spherical sac with thick parietes (1, *fig.* 226). The ovisacs (2) are racemose or connected in bunches, and attached in the Poulp to a single point of the ovarian capsule, but in the Eledone to about twenty separate stalks suspended from the upper part of the ovary. The ova, when detached from the ovisacs, escape by a single large aperture (3), leading from the anterior part of the sac into a very short single passage, which then divides to form the two oviducts. These tubes, in the unexcited state of the generative system, are membranous, straight, and of an uniform narrow diameter, except where they perforate a glandular laminated enlargement (4), situated about one-third from their commencement; but, towards the period of oviposition, the parietes of thé oviducts increase in thickness and extent, forming longitudinal folds internally.

The laminated glands doubtless serve to provide an exterior covering to the ova, and connect them together, thus performing the function of the accessory external glands in the preceding tribe. The oviducts ascend behind the lateral hearts and venous cavities, and open on each side of the mediastinal septum of the branchial cavity opposite the middle of the gills (5, 5).

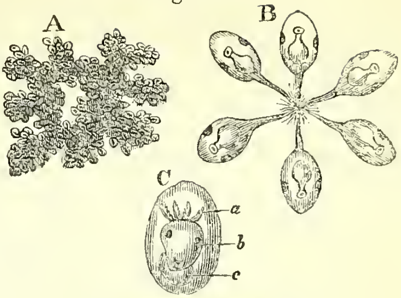
A glandular body surrounds each oviduct in *Eledone*, but is situated nearer the lower end of the tubes, and is of a darker colour than in *Octopus*.

In *Argonauta* the oviducts are continued by a short common passage from the ovary, and form several convolutions before they ascend to their termination, which is the same as in Octopus; they differ, however, from both the preceding genera in having no glandular laminated bodies developed upon them: the minute ova of this genus are, therefore, connected together by the secretion of the lining membrane of the long and tortuous oviducts.

Iu correspondence with the striking differences which the female organs present in the Cephalopodous class, it is found that almost every genus has its own peculiar form and arrangement of ova after their exclusion. Of these, therefore, we proceed to give a short description of the principal varieties.

The ova of the Argonaut are invariably found occupying a greater or less proportion of the bottom of the shell; they are of an oval form, about half a line in length before the develop-

Fig. 240.



Ova of the Argonaut.

Fig. 241.

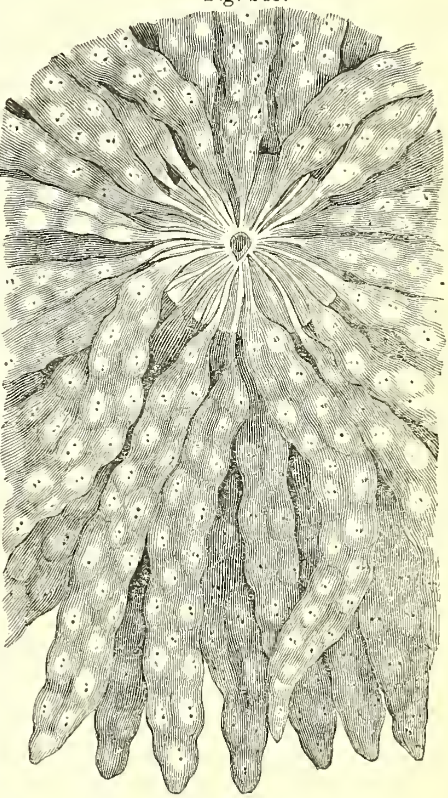


Fig. 242.

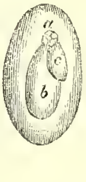
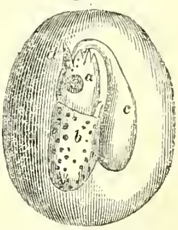


Fig. 243.



*Ova of the Calamary, Loligo Vulgaris.**

* From Férussac, *Monographie des Céphalopodes*.

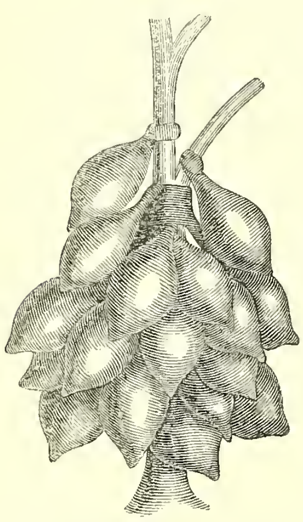
ment of the embryo has commenced, and are connected together in clusters by long filamentary processes.

In the figure subjoined, (*fig.* 240), A represents the ova of the natural size, B a group of ova at an early stage of embryonic development, magnified, C a single ovum, still more highly magnified, showing the embryo *a*, the rudimental feet *b*, and what would be regarded as the vitellus *c*, in the ovum of any of the naked Cephalopods, but which the continuator of Poli states to be the germ of the shell. With respect to the Poulp (*Octopus*) Aristotle states that the animals of this genus copulate in winter and bring forth in spring: that the female oviposits in a shell or some secure cavity; that the ova adhere in clusters, like the tendrils of the wild vine or the fruit of the white poplar, to the internal parietes of the cavity; that the young Poulps are hatched on the fifteenth day, and are then seen creeping about in prodigious numbers.*

The ova of the Calamary (*fig.* 241) are inclosed in cylindrical gelatinous sheaths, measuring from three to four inches in length, and about a quarter of an inch in diameter at the thickest part, narrowing to an obtuse point at one end, and attached at the opposite extremity by a filamentary process, varying from half an inch to an inch in length, to some foreign body, as floating wood, &c.; each sheath or nidamentum contains from thirty to forty ova, of a spherical figure, about a line and a half in diameter when newly excluded. As the number of cylinders attached to one body sometimes exceed two hundred, the prolific nature of the species may be easily conceived.

Fig. 242 shows the first appearance of the head and eyes *a*, at the stage prior to the development of the arms and funnel; *b* is the

Fig. 244.



Ova of the Cuttle-fish, Sepia Officinalis.

* Hist. Animal, lib. v. cap. 16.

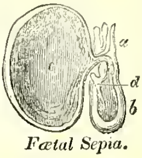
elongated body, *c* the yolk-bag. *Fig.* 243 is another ovum at a more advanced stage of development: the pigmentum is now deposited both in the rete mucosum and in the eye; the arms are just beginning to shoot from the anterior circumference of the head; and the little funnel may be observed rising above the ventral margin of the mantle.

The ova of the Sepioteuthis are also spherical and enveloped in cylindrical sheaths, but these are much shorter than in the Loligo, and contain much fewer ova, making an approach in this respect, as in the general organization, to the Sepiæ, in which each ovum has its own nidamentum.

The eggs of the Cuttle-fish (*fig.* 244) are of an oval form, attenuated at the extremities, enveloped in a flexible horny covering, of a blackish colour, which is prolonged into a pedicle at one extremity, and twisted round some foreign body. The length of ovum from the point of its attachment is generally an inch, and as a number of these ova are always found attached close together, and sometimes to one another, they resemble in this state a bunch of grapes, as the name 'sea-grapes,' commonly given to them by the fishermen, implies.

In the development of the Cephalopod the most interesting circumstance, and one which had not escaped the notice of Aristotle,* is the point of attachment of the yolk-bag (*c*, *fig.* 245), which is suspended from the head of the embryo, its pedicle being surrounded by the cephalic arms, and passing down anterior to the mouth to communicate with the pharynx. The yolk is a transparent gelatinous fluid of a spherical form.

Fig. 245.



Fœtal Sepia.

In the embryo of the Cuttle-fish all the organs, the exercise of which is essential to its future welfare, are adequately developed before its exclusion. The gills are very distinct, and the respiratory actions are vigorously performed by the alternate dilatation and contraction of the mantle and a corresponding elevation and falling of the funnel (*d*), by which the little streams are expired. The ink-bag has already provided a store of secretion sufficient to blacken a considerable extent of water, and baffle any enemy which may be ready to remove the little Cephalopod from the world into which it is about to enter. The pigment of the rete mucosum is developed in several large spots, as in the Calamary (*fig.* 243).

Five concentric layers of the dorsal shell at least are deposited; these are, however, horny, white, and transparent, except at the narrow and thick end; and the innermost layers are marked with irregular opake spots. The lateral fins are broad, and the ventral arms are furnished with a fin-like expansion, so that the young animal is enabled to execute movements either retrograde or progressive; and the eyes are well

* Προσπέφυκε δ' ἡ γιγνομένη σηπία τοῖς ᾠοῖς κατὰ τὸ πρόσθιον. 'Adhæret ovo Sepia nascens parte sui priore.' De Generatione Animalium, lib. iii. c. 8.

developed and proportionally large to direct its evolutions.

BIBLIOGRAPHY (ANATOMICAL). —— *Aristotle,* Historia de Animalibus, cur. Schneider, Lipsiæ, lib. iv. cap. 1, 2, & 4; lib. v. cap. 6 & 18; lib. vi. cap. 13; lib. viii. cap. 2 & 30; lib. ix. cap. 36. De Partibus Animalium, lib. iv. cap. 9.

In these several parts of his extraordinary work Aristotle indicates nine different species of Cephalopods, with so much precision and so happy a selection of their distinctive characters, that modern naturalists have been enabled to identify almost all the species which were studied by the Stagyrite two thousand years ago.

Of these we may first mention the *Nautilus which adheres to its shell,* and which we conceive may have been the *Nautilus Pompilius*; second, the *Nautilus which does not adhere to its shell,* universally allowed to be the *Argonauta* or Paper Nautilus of the moderns; third, the Cuttle-fish (*Sepia officinalis*); fourth and fifth, the great and small Calamaries (*Loligo vulgaris* and *Loligo media*); sixth and seventh, the great and small *Poulps*; the former is regarded by Belon and Rondeletius to have been the *Sepia octopodia* of Linnæus; but the small species, which Aristotle states to have been variegated,* has not yet been satisfactorily determined; eighth, the *Bolitæna,* a genus of Octopods which Aristotle characterized by its peculiar odour; this is the *Eledona moschata* of Leach; ninth, the Eledone, characterized by the single series of suckers, and to which the *Eledona cirrosa* of Leach corresponds.

Respecting the living habits of the Cephalopods, Aristotle is more rich in details than any other zoological author, and Cuvier has justly observed that his knowledge of this class, both zoological and anatomical, is truly astonishing.

Swammerdam, Biblia Naturæ, seu Historia Insectorum, 1737, 1738, or 'The Book of Nature,' &c. translated by Thomas Flloyd and J. Hill, London, 1758, fol. Towards the end of this work there is a letter from Swammerdam to Redi, in which are given the first anatomical details, in addition to those of Aristotle, which appeared after the revival of literature: the external parts and structure of the tongue are carefully described; the viscera and the nerves with less exactness; and the organs of circulation erroneously.

Needham, An account of some new microscopical discoveries, 8vo. London, 1745. At page 22 we find the first description of the armed suckers of the Calamaries: Chapter V. contains the curious account of the seminal filaments of the male Cephalopods.

Baker, An account of the Sea-Polypus; Philosophical Transactions, vol. 1. 1758. *Bohadsch,* Dissertatio de veris Sepiarum ovis, 4to. Pragæ, 1752. *Josephus Theophilus Koelreuter,* Polypi marini, Russis Karakatiza recentioribus Græcis οκτυπους dicti, descriptio. Nov. Comm. Acad. Petropol. tom. vii. p. 321-343, 1759. *Lamorier,* Anatomie de la Seche, et principalement des organes avec lesquels elle lance sa liqueur noire; Mém. de la Soc. de Montpellier, tom. i. p. 293-300, 4to. 1766.

John Hunter on the organ of hearing in fish; Philosophical Transactions, 1782. In this paper we find the first announcement of the existence of an organ of hearing in the class Cephalopoda. Numerous preparations in his Collection attest Mr. Hunter's extensive knowledge of the rich and singular organization of the Cephalopods: for his accurate description and beautiful figures of the circulating and respiratory organs, the reader is referred to the second volume of the Descriptive and Illustrated Catalogue to the Hunterian Collection, 4to. and to the first volume of the same work, for the descriptions of his preparations of the hard parts and digestive organs of the Cephalopods: among the latter Mr. Hunter had placed the 'Pancreas of the Cuttle-fish.'

Monro (Secundus). The structure and physiology of fishes explained, &c. fol. Edinburgh, 1785. This work contains (p. 62) the anatomy of the Sagittated Calamary (*Loligo sagittata,* which the author terms the *Sepia loligo*), and from its organization he ably deduces its true place in the natural system, observing that 'by most authors it has been ranked among Fishes; by Linnæus it has been placed among the worms: but perhaps it may most justly be considered as a link connecting the two classes of animals.' Monro confirms the discovery of Hunter of the acoustic organ, and figures the otolithe of the Calamary. He first published the true description of the three hearts, and rectified the errors of Swammerdam on this part of the anatomy of the class: he notices the absence of the venæ portæ, and some of the peculiarities in the structure of the eye; but his description of the generative system, and his notice respecting some other particulars, as the urinary and gall-bladder, are erroneous.

Scarpa, Anatomicæ disquisitiones de auditu et olfactu, fol. 1789. The anatomical descriptions relative to the Cephalopods are limited chiefly to the organ of hearing, and the course of the nerves; the account of the latter is incomplete and in part erroneous.

Tilesius, in the Beiträge für die Zergliederungskunst von H. F. Isenflamm, B. 1. Heft. 2.

G. Cuvier, Lecons d'Anat. Comparée, 1799 to 1805. These five volumes contain the results of numerous researches on the anatomy of the Cephalopoda, all characterized by the author's usual depth and accuracy. They are collected together with additional details and beautiful figures in the celebrated 'Mémoire sur les Céphalopodes et leur Anatomie,' published in 1817, in the Mémoires sur les Mollusques, 4to. The type of organization illustrated by these researches is considered in the author's subsequent work (the *Règne Animal*), as characteristic of the class Cephalopoda; but the chief peculiarities are found only in the Dibranchiate Order.

De Blainville, De l'organization des animaux, ou principes d'anatomie comparée, tom. i. 8vo. 1822. Contains observations on the skin and organs of sense of the Cephalopods. *Ejusdem,* Manuel de la Malacologie, 8vo. 1825.

Home (*Sir Everard*), Lectures on Comparative Anatomy, 4to. 1814-1828. On the distinguishing characters between the ova of the Sepia and those of the Vermes testacea. *Philos. Trans.* cvii.

Leach, (*W. E.* M.D.) On the genus Ocythoë. Phil. Trans. cvii. Appendix to Tuckey's Voyage to the Congo. Zoological Miscellany, vol. iii.

Rathke, Ueber Perothis, &c. (on the anatomy of the *Loligopsis*); Mém. de l'Acad. Imp. de Petershourg, tom. ii. parts 1 & 2, p. 169, 1833.

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Robert Grant, M.D. &c. Description of a new species of Octopus (*Oct. ventricosus,* Grant); Edinb. Philos. Journal, vol. xvi. p. 309. On the structure and characters of *Loligopsis,* &c. and on the anatomy of the *Sepiola vulgaris,* Leach. Transactions of the Zoological Society, part i. 4to. 1833. Lectures, Lancet, 1833-4. Outlines of comparative anatomy, parts 1 & 2, 8vo. 1835.

Delle Chiaje, Memorie sulla storia degli animali senza vertebre del regno di Napoli, 1823-1829, 4 vol. 4to.

San Giovanni, Giornale Encicl. di Napoli, 1824; Annales des Sciences Naturelles, tom. xvi. p. 305. (His memoirs on the structure and properties of the colorific stratum of the skin of Cephalopoda are contained in the above works.)

J. Coldstream, M.D. see Edinh. New Philosophical Journal, July, 1830, p. 240; and, On the development of the ova of *Sepia officinalis,* Proceedings of the Zoological Society, part i. 1833, p. 86.

Mayer, Analekten fur Vergleichenden Anatomie, 4to. 1835.

* Ἔτι δὲ ἄλλοι μικροὶ, ποικίλοι, οἳ οὐκ ἐσθίονται.

Férussac, M. le Baron, & A. D'Orbigny, Monographie des Céphalopodes Acétabulifères, folio, Paris, 1835. This splendid work is published in numbers, of which eleven have appeared. As yet the letter-press extends only to the general introduction.

Broderip, (W. J.) Observations on the animals hitherto found in the shells of the genus Argonauta, Zoological Journal, vol. iv. p. 57.

Richard Owen, Memoir on the Pearly Nautilus (*Nautilus Pompilius,* Linn.) 4to. 8 plates, 1832. This work contains, besides the description of the structure which characterizes the lower or Tetrabranchiate order of the class, some additional particulars on the structure of the infundibulum, and of the brain, and on the function of the superadded branchial hearts, in the Dibranchiate order of Cephalopods. Descriptive and illustrated Catalogue of the Physiological Series in the Museum of the Royal College of Surgeons, 4to. vol. iii. contains an account of the organs of sight and hearing in the Cephalopods, 1835. Description of a new genus of Cephalopoda (Rossia). Appendix to Sir John Ross's Voyage, 1835. Descriptions of some new species; and anatomical characters of the Orders, Families, and Genera of the class Cephalopoda, Proceedings of the Zoological Society, March, 1836.

(*Richard Owen.*)

CERUMEN, (Germ. *Ohrenschmalz.*)—This secretion, formed by the glands of the external ear, has been examined by Fourcroy and Vauquelin, and more in detail by Berzelius.* According to Vauquelin it consists of 0·625 of a brown butyraceous oil, soluble in alcohol, and 0·375 of an albuminous substance, containing a peculiar bitter extractive matter. Berzelius observes, that, when first secreted, cerumen appears as a yellow milky fluid, which gradually acquires a brownish colour and viscid consistency. Digested in ether it imparts to it fatty matter, which remains when the ethereal solution is distilled off water; it has a soft consistence, is nearly colourless, and contains stearin and elain separable by alcohol; it is easily saponified, and the soap which it forms has a rank unpleasant smell and taste; and when decomposed by muriatic acid, the fatty acids separate in the form of a white powder, which rises with difficulty to the surface, and fuses at about 105°. The portion which remains after the action of ether imparts a yellow colour to alcohol, and on its evaporation there remains a yellow-brown extractive matter, soluble in water, and leaving after the evaporation of its aqueous solution a yellow, transparent, and shining varnish, which is viscid and inodorous, but intensely bitter; when burned, it exhales a strong animal odour, and leaves an ash of carbonate of potash and carbonate of lime, without any trace of a chloride. It is completely precipitated from its aqueous solution by neutral acetate of lead. That part of cerumen which is not soluble in alcohol yields to water a small proportion of pale yellow matter, which, when obtained by evaporation, has a piquante taste; it is not precipitable by salts of lead, corrosive sublimate, or infusion of galls, and contains no traces of phosphoric or chlorine salts. The residue of the cerumen, insoluble in water and alcohol, gelatinises in acetic acid, but is only partially dissolved by it; that which is taken up appears to be albumen; and the undissolved portion is brown, viscid, and transparent; digested in dilute caustic alkali it imparts a yellow colour, but a small portion only is dissolved; and as nothing is thrown down by supersaturation with acetic acid and ferrocyanate of potash, it is not albumen that is taken up: the acid solution, however, is copiously precipitated by infusion of galls, so that it contains some peculiar principle. The residue which resists the action of dilute alcali, when boiled in concentrated solution of caustic potash, becomes brown, and smells like horns imilarly treated; a part of it seems to form a compound with the alkali insoluble in the ley, but soluble in water, in which respect it resembles horn, but it differs from it in not being precipitated from its solution by muriatic acid, nor ferrocyanate of potash, and scarcely by infusion of galls. It appears, therefore, that cerumen is an emulsive combination of a soft fat and albumen, together with a peculiar substance, a yellow and very bitter matter soluble in alcohol, and an extractive substance soluble in water: its saline contents appear to be lactate of lime and alkali, but it contains no chlorides and no soluble phosphates. When cerumen accumulates and hardens in the ear so as to occasion deafness, it is easily softened by filling the meatus with a mixture of olive oil and oil of turpentine, by which its fatty matter is dissolved.

(*W. T. Brande.*)

* Lehrbuch der Thierchemie.

CERVICAL NERVES. See Spinal Nerves.

CETACEA; Gr. κητη, δελφινοι, Aristotle; Eng. Whale tribe, Cetaceans; Fr. *Cetacés;* Germ. *Wall-fische.*

[An order of mammiferous animals, distinguished, as regards outward characters, by the absence of hinder extremities, neck, hair, and external ears; and by the presence of a large horizontal caudal fin, and the fin-like form of the anterior extremities, the bones of which are shortened, flattened, and enveloped in a thick unyielding smooth integument. With this configuration the Cetaceans are fitted only for aquatic life, and reside habitually in the waters of the sea or of large rivers: their resemblance to the true Fishes is so close that many naturalists, since the revival of literature, and the vulgar in all ages, have regarded them as members of the same class. Aristotle, from his anatomical knowledge, was aware of the essential differences between the Whales and Fishes, but it is not absolutely necessary to seek for internal characters to establish the real distinction which subsists between these different denizens of the deep; the horizontal position of the tail-fin at once distinguishes the cetacean from the fish, in which that fin is vertical. This difference relates to the different nature of the respiration of the Whale, which is by lungs, and consequently necessitates a frequent rising to the surface of the water to breathe the air, and a corresponding modification of the chief organ of locomotion.

With the lungs are also associated the presence of warm blood, a double circulation, an epiglottis, and a diaphragm, a true viviparous generation, a nourishment of the young by a mammary secretion, and in short all the essential parts of a mammiferous organization.

The order is subdivided as follows:

Tribe I. *PHYTOPHAGA.*

Char. *Teeth* of different kinds; *molars* with flattened crowns, corresponding to the vegetable nature of their food. *Mammæ*, two, pectoral. *Lips* provided with stiff bristles. *External nostrils*, always two, situated at the extremity or upper part of the rostrum, which is obtuse.

Genus MANATUS, Cuv.

Char. *Incisors* $\frac{0}{0}$ (two superior, deciduous in the fœtus, not replaced). *Molars* $\frac{8}{8}\frac{8}{8}$, grinding surface with tri-tuberculate transverse ridges. *Body* with a few scattered bristles. *Anterior extremities* each provided with four nails. *Tail-fin* oval.

Species 1. *Manatus Americanus*, Cuv. *Trichechus Manatus*, Linn.: the Manatee. Lamantin d'Amérique, Cuv.

2. *Manatus Africanus*, Lamantin du Senegal, Cuv.

Genus HALICORE, Cuv.

Char. *Incisors* $\frac{2}{0}$. (In the young animal the two superior permanent incisors are preceded by two deciduous ones; six or eight deciduous incisors in the lower jaw which have no permanent successors). *Molars* $\frac{2}{2}\frac{2}{2}$; (in the young animal $\frac{5}{5}\frac{5}{5}$); the grinding surface exhibits a rim of enamel at the circumference and a slightly excavated centre of ivory. *Body*, with a few scattered bristles. *Upper lip* with bristly mustaches. *Anterior extremities* without nails. *Tail-fin* very broad, crescentic.

Species 1. *Halicore Indicus*, Cuv. The Indian Dugong, or, more properly, Duyong.

2. *Halicore Tabernaculi*, Ruppel. Dugong of the Red Sea.

Genus RYTINA, Illiger. *Incisors* none. *Molars* $\frac{1}{1}\frac{1}{1}$, large, lamelliform, of a fibrous structure, with the triturating surface roughened by tortuous furrows. *Body*, without hairs, but covered by a rough and thick fibrous epidermis. *Anterior extremities* terminated by an unguiform callosity. *Caudal-fin* crescent-shaped, each angle terminated by a horny plate.

Species. *Rytina Stelleri*, Le Stellère, Cuv. This species inhabits the seas of Kamtschatka. It was discovered by the Russian naturalist, Steller, after whom it is named; and is described by him with much zoological and anatomical detail in the *Nova Comment. Petrop.* t. ii. p. 294, (1751,) under the name of the *Manati* or *Vacca marina*.

Tribe II. *ZOOPHAGA.*

Char. *Teeth* of one kind or wanting, not adapted for mastication. *Mammæ*, two, pudendal. *External nostrils*, double or single, situated on the top of the head.

A. with the head of moderate size.

Family DELPHINIDÆ. *Teeth* in both jaws, all of simple structure, and generally conical form. No cœcum.

Genus DELPHINORHYNCHUS. *Rostrum* very long and narrow, continued not abruptly from the forehead. *Teeth* very small and numerous.

Ex. *Delphinorhynchus micropterus.* (Fred. Cuvier, Cetacés, pl. viii. fig. 1.)

Genus DELPHINUS. *Rostrum* narrow, of moderate length, continued abruptly from the forehead. *Teeth* conical, slightly recurved, numerous.

Ex. *Delphinus Delphis*, the common Dolphin; *Delphinus Tursio*, the Spouter or small Bottle-nose Whale of Hunter.

For the other numerous species of this genus consult F. Cuvier, Histoire des Cetacés, p. 147 et seq.

Genus INIA. *Rostrum*, as in the genus *Delphinus*. *Teeth* mammilliform.

Species. *Inia Boliviensis;* (Fred. Cuvier, Cetacés, pl. x, bis, and xi, cranium); inhabits the great rivers of South America.

Genus, PHOCÆNA. *Rostrum* short, broad. *Teeth* conical or compressed.

Ex. *Phocæna communis*, the common Porpoise; *Phocæna orca*, the Grampus; *Phocæna globiceps*, L'Epaulard, Cuv. *Phocæna leucas*, the Beluga,* &c.

The following genera seem to form the types of as many distinct families of Zoophagous Cetaceans.

Genus MONODON. *Rostrum* short and broad. No other *teeth* save two in the upper jaw, in the form of tusks, situated horizontally, and both of which continue in the rudimental condition in the female, while in the male one projects far beyond the jaws in the line of the axis of the body.

Ex. *Monodon monoceros*, Linn. The Narwhal.

Genus HYPEROODON. *Rostrum* of moderate length, extending abruptly from a very elevated cranium. Two small *teeth* in the lower jaw; small callous tubercles on the palate.

Ex. *Hyperoodon Dalei;* the great Bottle-nose Whale of Hunter.

Genus PLATANISTA. *Rostrum* very long and compressed, enlarged at the extremity. *Teeth* numerous; in both jaws conical and recurved. Cranium enlarged by osseous processes. A cœcum.

Ex. *Platanista Gangetica.* The Gangetic Dolphin.

* This species has no dorsal fin, and on that account has by some naturalists been regarded as forming the type of a distinct genus, under the name of *Delphinapterus*.

B. With the head of immoderate size, equalling one-third the length of the body.

Family I. CATODONTIDÆ. *Teeth* numerous, conical, but developed only in the lower jaw. *External nostrils* or blow-holes confluent; no cœcum.

Genus Catodon. No dorsal fin.

Ex. *Catodon macrocephalas; Physeter macrocephalus,* Shaw. The great Spermaceti Whale.

Genus Physeter. A dorsal fin.

Ex. *Physeter Tursio,* Linn. The High-finned Cachalot, Shaw.

Family BALÆNIDÆ. No teeth; their place supplied by the plates of baleen or whalebone attached to the upper jaw. Blow-holes distinct; a cœcum.

Genus Balænoptera. A dorsal fin; pectoral integument plicated; baleen-plates short. (*See fig.* 259.)

Species. *Balænoptera Boops,* Cuv.; the Jubarte or great Rorqual.

Balænoptera rostrata, Lacép.; the Piked Whale of Sibbald and Hunter, suspected by Cuvier to be the young state of the *Balænoptera Boops.*

Balænoptera Muscalus, Cuv.; the Mediterranean Rorqual.

Balænoptera Antarctica, Cuv.; the Southern or Cape Rorqual.

Genus Balæna. No dorsal fin; pectoral integument smooth; baleen-plates long.

Species. *Balæna mysticetus,* Linn. The great Whalebone Whale of Hunter; great Mysticete.

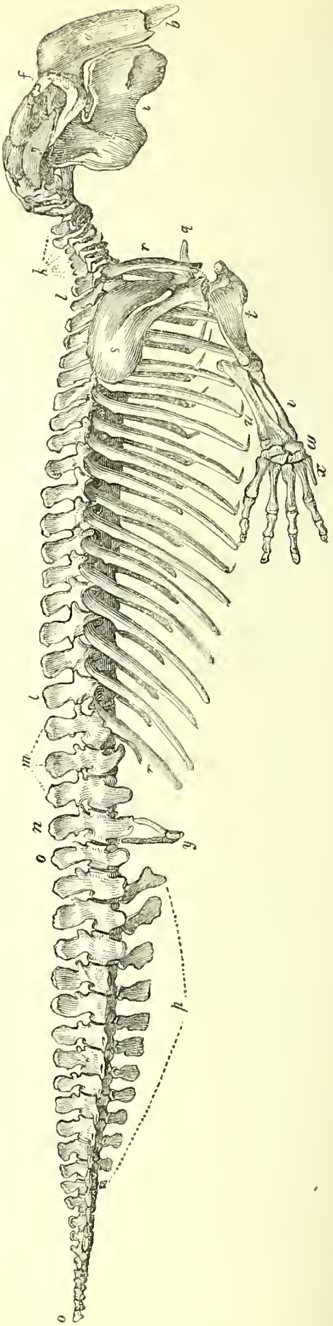
Balæna Australis, Cuv. The Cape Whale.]

Organs of Motion.—Swimming is the principal mode of progression of the Cetaceans, but the Phytophagous species appear to have the power, in order to feed upon marine plants, of crawling and walking at the bottom of the sea by means of their anterior members, which in other Cetaceans are exclusively natatory organs.

The head, in all, has so little mobility, that its axis can be but slightly altered, without that of the body altering also.

In the form and composition of the skull the Cetaceans of both tribes present many important differenees, as compared wtth other mammiferous animals. In the Herbivorous genera the bones are densc and massive, and where they are not anchylosed their connection is of a loose kind. In the Dugong the skull is more especially remarkable for the large size of the intermaxillary bones (*a, a, figs.* 246, 247), which extend backwards as far as the middle of the temporal fossæ, and are bent down anteriorly over the symphysis of the lower jaw, so as to terminate nearly on a level with its inferior margin. This extent and shape is required in the Dugong for the lodgement of the permanent incisors (*b, b*), which are developed to a large size, one in each intermaxillary bone, and consequently the nostrils are placed much higher and further from the mouth than in the Manatee, in which, in consequence of the small deciduous incisors having no successors, the

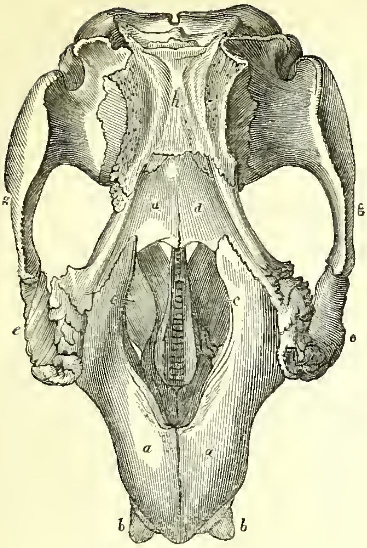
Fig. 246.



Skeleton of the Dugong.

intermaxillary bones are of much smaller size. The form of the bony aperture of the nostrils (*c, fig.* 247) in both the Dugong and Manatee is a large oval, which in the Dugong, as in the typical Cetaceans, is directed upwards. The entire cranium, and especially the frontal boncs

Fig. 247.



Skull of the Dugong.

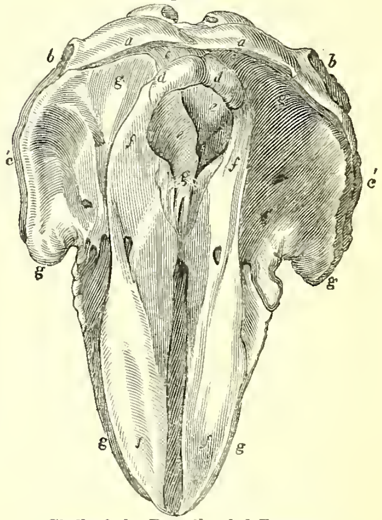
(d, d), are consequently proportionally shorter than in the Manatee. The processes of the frontal bone, which form the superior boundary of the orbits, are thinner and more rugose in the Dugong; the portion of the superior maxillary bone, which serves as the floor of the orbit, is narrower; the malar bone *(e, e, figs.* 246, 247), which forms by its curvature the anterior and inferior margins of the orbit, is more compressed and descends lower down. The lachrymal bone, which is situated at the anterior angle of the orbit *(f, fig.* 246), is of larger relative size than in the Manatee; but, as in that species, it is imperforate. The zygomatic process of the temporal bone *(g, figs.* 246, 247), which, in the Manatee, is proportionally thicker than in any other animal, is of more ordinary dimensions in the Dugong, being more compressed, and extended further backwards. The connexions of the bones of the cranium are the same in both these herbivorous species. The parietal bones *(h, fig.* 247) are developed in the fœtus, as usual, each from a distinct centre of ossification; but, what is very remarkable, the ossification of the interparietal bone also proceeds from two lateral and symmetrical points: these four, originally distinct bones, are, however, very early anchylosed together, and also to the superior occipital bone, which latter junction takes place before the three other elements of the occipital bone have coalesced. The parietal cristæ are widely separated from each other. The occiput is narrower, and its crest is less marked than in the Manatee. In the interior of the cranium we may observe that there is no bony tentorium, and that the cribriform plate of the ethmoid is reduced to two simple depressions, widely separated from one another, and terminating anteriorly in two or three small foramina. There is no *sella turcica* for the pituitary gland. The optic foramen presents the form of a long and narrow canal.

The lower jaw *(i, fig.* 246) corresponds in depth to the curvature and length of the intermaxillary bones, and is bent downwards at the symphysis in a corresponding direction, presenting on the anterior surface of this part three or four rough and shallow alveoli, in two of which Sir Everard Home* discovered a small rudimental incisor.

The skull of the true or Zoophagous Cetaceans is characterized by the great breadth and elevation of the cranium, by the almost vertical direction of the nasal passages, by the depressed position of the orbits as compared with the bony nostrils,—a character which is still more marked in these than in the herbivorous species; and, lastly, by the extreme prolongation of the oral or labial portions of the intermaxillary and maxillary bones. The superior maxillaries *(g, g, fig.* 268) are also developed posteriorly so as to rise anterior to the frontal bones, over which they are expanded, extending as far as the level of the nasal bones, which form almost the summit of the cranium. Such at least is the general configuration of the skull in the *Delphinidæ*, which constitute the largest family of the Zoophagous tribe.

In the *Phocæna globiceps*, of which the skull is represented in *fig.* 248, the cranium is very

Fig. 248.



Skull of the Roundheaded Porpesse; Phocæna globiceps.

convex behind; the occipital crest *(a, a)* surrounds the upper part and descends on each side to the middle of the temporal cristæ: the posterior convexity is not formed by the occipital bone alone, but also by the interparietal and parietal bones *(b, b)*, the whole being anchylosed together at a very early period. The parietal bones descend, as in the human subject, between the temporal and the frontal *(c, c)*, and reach the lateral ala of the posterior sphenoid. As the parietals terminate behind the

* See Pl. xiv. Philos. Trans. 1820.

transverse superior cranial or occipital ridge, and the superior maxillary bones approach very close to the same part, the frontal bone seems to be represented by a very narrow osseous band traversing the cranium from right to left, and dilating at each extremity to form the roof of the orbit *(c′, c′)*. But when the maxillary bones which have extended over the whole anterior part of the cranium are raised, the frontal bone is then seen to be of much larger size than the external appearances indicate.

The two nasal bones *(d, d)* are in the form of oblong rounded tubercles, set deeply in two depressions in the middle of the frontal bone, and in front of which the nasal passages *(e, e)* are continued vertically downwards. The two intermaxillaries *(f, f)* form the external and anterior margin of the nasal apertures. The cribriform plate of the *ethmoid* constitutes the posterior wall of the nasal passages; and in this plate there are three or four small perforations. The remainder of the circumference of the bony nostrils is formed by the maxillary bones, of which a small part appears at *g*: their septum is the *vomer*, which is joined to the ethmoid as usual.

The malar bone is an irregular flattened bone, which assists the frontal in forming the orbit, and, like it, is covered by the maxillary bone: it sends backwards a long and slender process, which articulates with the zygomatic process of the temporal bone, and forms the only bony boundary of the lower part of the orbit. The zygomatic process of the temporal bone is united to the post-orbital process of the frontal, bounding the orbit posteriorly; and thus the zygomatic arch is exclusively formed by the temporal bone: this bone terminates at the temporal ridge, having but a small extent of development on the side of the cranium, and not entering at all into the composition of the posterior convex surface. At the base of the cranium the basilar and the lateral occipitals develop expanded plates, which join the pterygoideal alæ of the sphenoid, and a lamina of the temporal bone, to which the petrous and tympanic bones have a ligamentous attachment. The parietal bones also extend behind the temporals, to aid in completing the basilar walls of the cranial cavity, so that the temporal bone is almost excluded from entering into the composition of the cranium, serving merely to close some small vacancies left by the parietals: this structure is of great interest, as we perceive in it the commencement of that displacement of the temporal bones from the cranial parietes which is characteristic of the small-brained and cold-blooded classes of Vertebrata.

The differences between the Dugong and Manatee in respect to the structure of the cranium, we have seen to resolve themselves almost entirely into the expansion and elongation of the intermaxillary bones in relation to the tusks, which they are destined to support in the former animal; and we shall find on a comparison of the skulls of the *Delphinidæ* together, that they also differ from one another, chiefly in the forms and proportions of their maxillary and intermaxillary bones.

The *Delphinorhynchi* are characterized, first, by an extremely narrow *rostrum*, the length of which is four times greater than that of the cranium; secondly, by the anterior curvature of the posterior extremities of the intermaxillaries, which, as it were, draw forwards in the same direction the maxillary, the frontal, and even the occipital bones; thirdly, by the position of the nasal bones, which are sunk in between the frontals and intermaxillaries; fourthly, by the very diminutive size of the temporal fossæ.

The *Delphini*, properly so called, have also a narrow rostrum, but its length is scarcely three times that of the cranium; the posterior extremities of the intermaxillary bones, together with the maxillary and frontal bones, are raised, but not bent forwards; the temporal fossæ in some species are as diminutive as in the *Delphinorhynchi*, but in others gradually recede from that character, and approach, by their expansion, to the form which they exhibit in the next generic type, viz. the *Inia*.

The cranium in this genus, besides the great extent of the temporal fossa, and the strong crista which forms its superior border, is also characterized by the shortness of the orbital fossa.

In the *Phocænæ* the rostrum is as remarkable for its breadth as it is in the *Delphini* for its narrowness; this results from the great lateral development of the intermaxillary and maxillary bones; but the antero-posterior extension of the bones is diminished, and the length of the rostrum does not exceed that of the cranium.

The Narwhals *(Monodon)* manifest their affinity to the Porpesses *(Phocæna)* by the breadth and shortness of the rostrum, but differ from that and every other genus of Cetacea in the development of horizontal tusks in the intermaxillary bones, of which the left in the male and both in the female remain concealed in a rudimental state within the maxillary bones.

The cranium in the genus *Hyperoodon*, which includes the Great Bottle-nose Whale of Hunter, is at once distinguishable by the remarkable vertical crest which rises from the middle of the maxillary bones, the contour of which process descends suddenly behind, but extends more gradually and obliquely downwards anteriorly. The lower jaw in this genus has two rudimental teeth at its anterior part.

Lastly, in the Gangetic Dolphin *(Platanista)* the cranium presents a marked resemblance to that of the *Delphinorhynchus* in the length and narrowness of the rostrum, and in the elevation and anterior curvature of its base; but on pursuing the comparison in detail, the structure and composition of this part of the skeleton presents several fundamental differences, which at the same time indicate an affinity to the Cachalots *(Physeter)*. The most striking character in the cranium of the Platanista is presented by the maxillary bones, which, after having covered, as in the other *Delphinidæ*, the frontal bones as far as the temporal cristæ, give off respectively a large osseous expansion, which arches forwards and forms a capacious vault above the spouting apparatus of the nostrils. In order to constitute this part, one of the processes inclines towards the other, so as almost to come in contact with it for the two anterior thirds; but posteriorly they recede from one another to give passage to the blow-hole. The cavity beneath this singular bony pent-house is occupied by an interlacement of numerous osseous processes, and by a close and hard fibrous substance.*

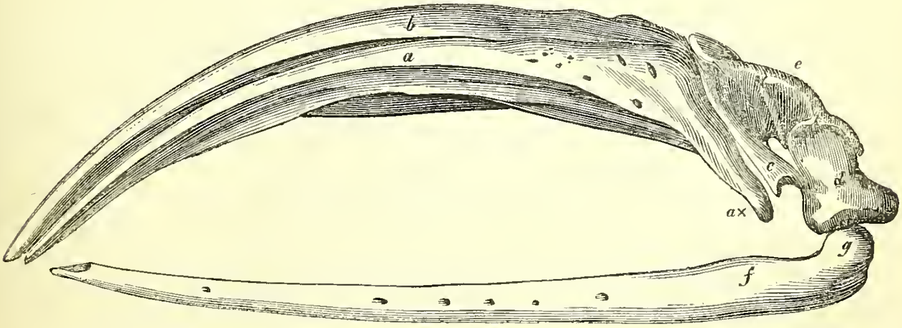
If we suppose the cranium of a Dolphin to be proportionally very much shortened, the margins of the rostrum to be greatly expanded and raised, so as to render its superior surface concave; the supra-frontal portions of the maxillary bones to be much developed and the margins extended upwards, thus forming an immense basin, at the bottom of which lie the external orifices of the bony nostrils; if also the occipital crest in the Dolphin were raised behind the maxillaries so as to aid them in the formation of the bony cavity, in the basis of which the parietals are almost concealed, we should then have the skull of a Cachalot. The rostrum in the *Catodontidæ*, notwithstanding its immense size, is formed principally by the maxillary bones, as the intermaxillaries and the vomer constitute a comparatively small part of the intermediate portion. The nasal passages extend obliquely from below upwards and forwards, but are of very unequal dimensions, the one on the right side not having one-fourth the breadth of that on the left. A corresponding want of symmetry is shown in the nasal bones themselves, and the cranium generally; and this circumstance, it may be remarked, characterizes in a greater or less degree the skull in all the Zoophagous Cetacea.

The skull in the Whalebone-Whales (*Balænidæ*) is, however, the most symmetrical in its general form; it is characterized by the great relative predominance of the facial over the cranial portion, by the narrowness of the rostrum, and the curvature of the rami of the lower jaw, which each extend outwards, in a convex sweep, far beyond the sides of the upper maxilla, and converge to the symphysis, but without meeting to form a bony union at their anterior extremities.

In the Mysticete, or common Whalebone-Whale (of which a side view of the skull is given at *fig.* 249) the immense maxillary bones (*a, a*) are compressed, and disposed each like an expanded arch along the outside of the intermaxillaries (*b*) and the vomer; their inferior surface has two facets separated by an intermediate longitudinal ridge, to the sides of which the plates of whalebone or baleen are attached (*b, fig.* 259). The intermaxillary bones are also laterally compressed, and diverge from each other posteriorly to form the long elliptical bony outlet of the nostrils; this orifice is completed behind by the nasal bones, which are of very small size, and are partially covered by the frontal bones, which project forwards above them in the form of two small points. The tranverse portions of the frontal (*c*) and maxillary (*a**) bones, which contribute to form the orbits, extend obliquely backwards: the temporal bone (*d*) is of an irregular quadrate form, and extends much further backwards even than the occipital condyles. The occipital bone (*e*) advances forwards so as to cover almost all the upper part of the cranium, where it presents a general convexity. Each ramus of the lower jaw (*f*) is convex externally, compressed and somewhat trenchant both at the upper and lower margins. The coronoid process, on which the letter is placed, is in the form of a slightly raised obtuse angle; the condyloid process (*g*) forms the large tuberosity behind. It is articulated to the glenoid cavity by a mass of ligamentous fibres, and not by a capsular ligament surrounding a synovial cavity.

The vertebral column of the *Cetacea* does not differ from that of other *mammalia* except in the modifications demanded by their peculiar mode of existence. The cervical vertebræ, of the normal number of seven, with the exception of the Manatee, are in general extremely thin, and though in some species, such as the Manatee, the Dugong (*k, fig.* 246), and the

Fig. 249.

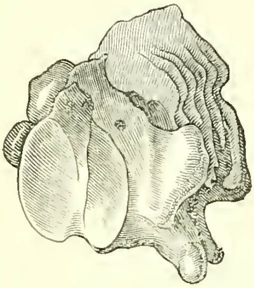


Platanista, they are found free; others, as the Dolphins and Porpesses, have the first two commonly anchylosed together. In the Balæ-

* For a detailed account of the structure of the skull in this singular fresh-water Cetacean, see Cuvier, Ossémens Fossiles, v. pt. i. p. 298.

nopteræ the dentata is anchylosed at its upper part to the third cervical vertebra. In the Cachalots they are the six last vertebræ which re thus found united to one another, and in the Whales, properly so called, or *Balænæ*, all he seven are anchylosed. (See *fig.* 250.)

Fig. 250.

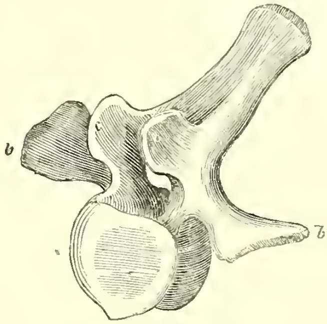


Cervical vertebræ of a Whale, Balæna Australis.

The dorsal vertebræ (*l*, *fig.* 246), the number of which varies according to the species, are characterized by having their spinous processes, bent backwards, elongated from the first to the last, and equalled in length by the transverse processes. Moreover, their posterior articulating processes disappear after the first vertebra, and the anterior ones soon cease to perform the functions of parts concerned in the union of the vertebræ to one another.

In *fig.* 251, which represents the eleventh dorsal vertebra of the Cape Whalebone Whale, *a* is the spinous; *b*, *b*, the two transverse, which begin to lengthen from this point in the succeeding vertebræ; *c*, *c*, the anterior articulating processes.

Fig. 251.

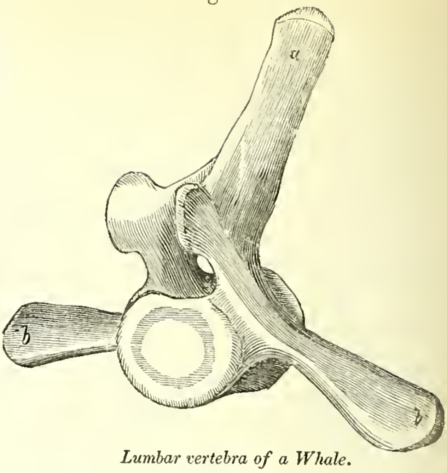


Dorsal vertebra of a Whale.

The lumbar vertebræ (*m*, *fig.* 246), the posterior limit of which it is difficult to determine in animals devoid of pelvis, have their spinous (*a*, *fig.* 252) and transverse processes (*b*) very long. The first are straight and slightly inclined backwards.

As it is essential that the Cetaceans should have the posterior part of their vertebral column left free, to allow of the vigorous inflexions of the tail required in the act of

Fig. 252.

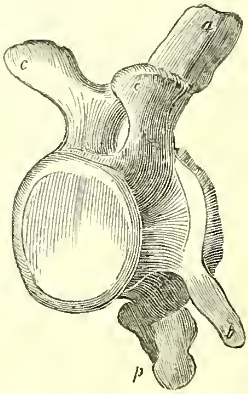


Lumbar vertebra of a Whale.

swimming, none of the vertebræ are anchylosed together or encumbered by a union with posterior extremities, and hence there are none which can be properly termed sacral, unless we regard the sacrum as represented by the single vertebra, (*n*, *fig.* 246,) to which, in the Dugoug, the pelvic bones are suspended. The caudal vertebræ may then be considered to commence from this point. Most of these vertebræ (*o*, *fig.* 246) are further characterized by the chevron bones, (*p*, *figs.* 246, 253,) which at first are strong and well developed, but together with the other processes gradually diminish and disappear towards the extremity of the vertebral column, where the centres or bodies of the vertebræ alone appear, and present a depressed flattened form corresponding to the horizontal position of the caudal fin, which characterises these air-breathing inhabitants of the ocean.

Fig. 253 represents one of the anterior caudal vertebræ of the Cape Whale: *a* is the spinous; *b* the transverse; *c*, *c*, the representatives of the anterior oblique processes; *p* the inferior spinous processes, or chevron bones.

Fig. 253.



Caudal vertebra of a Whale.

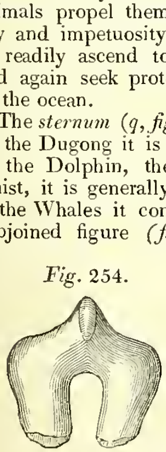
To bones so little mobile, and so rudimental as the vertebræ of the neck in Cetaceans, muscles proportionately developed should correspond, and such in fact is the case. The cervical muscles in these animals are the same in number as in other Mammals, but their shortness and thinness, principally in those attached to the atlas and the axis, are extreme; and although those which proceed from the other cervical vertebræ may be better characterized, their action, nevertheless, is not much more extensive.

The muscles of the back present no other important modifications than their great development and their prolongation even upon the coccygeal vertebræ. Thus the *longissimus dorsi* and the *sacro-lumbalis* are attached anteriorly to the skull, and posteriorly transmit their tendons, the first to the end of the tail, the second to all the transverse processes of this part of the spine, associating in this way the movements of the back with those of the tail. As to the muscles peculiar to the tail, besides those which belong to this organ in all Mammals where it exists as a moveable organ, there are besides, in the Cetaceans, 1st, the antagonists of the *sacro-lumbalis* below the transverse processes; 2nd, a *levator caudæ*, which takes its rise above the five or six dorsal vertebræ, under the *longissimus dorsi*, and often in this part blends with it; it then extends freely as far as the extremity of the tail, where the two muscles unite together again by their tendons; 3rd, a *depressor caudæ*, of great thickness, which proceeds from the pectoral region, and spreads its tendinous processes upon the ribs, distributes them laterally to the transverse processes, and below to be inserted into the chevron bones along the two posterior thirds of the tail; 4th, a muscle which comes from the rudimental bones of the pelvis, and is inserted into the chevron bones of the anterior portion of the tail; 5th, the great *recti* muscles and the *obliqui ascendentes*, which, proceeding from the abdomen, attach themselves behind to the sides of the base of the tail.

It is in consequence of this great aggregation of muscles, which are developed in unexampled proportions as compared with other Mammals, that the tail of the Cetaceans acquires the prodigious strength which it possesses, and by means of which these gigantic animals propel themselves with so much facility and impetuosity through the water, and so readily ascend to the surface to respire, and again seek protection in the deep abysses of the ocean.

The *sternum* (*q*, *fig*. 246) is short and large. In the Dugong it is composed of five pieces; in the Dolphin, the Porpesse, and the Platanist, it is generally composed of only three; in the Whales it consists of but one. In the subjoined figure (*fig*. 254) from the *Balænoptera Boops*, the sternum is deeply notched behind, and has a large ridge on its exterior or under surface.

Fig. 254.



The *ribs* of the Cetaceans are chiefly remarkable for their great curvature, but differ in their relative length, thickness, and mode of connection.

Their thickness and the density of their texture is most remarkable in the Herbivorous species, especially in the Manatee. In the Dugong, which has eighteen pairs of ribs (*r*, *r*, *fig*. 246), only the first three have cartilages which join the sternum. In the *Delphinidæ* the first pair of ribs are articulated at their sternal extremities to the anterior angles of the first bone of the sternum; the second pair join the sternum between the first and second bones; the third between the second and third, and the fourth, fifth, and in some species the sixth pairs of ribs are joined to the third bone of the sternum; the sternal portions of these ribs are ossified. The anterior ribs are articulated at first by a head to the vertebral centres, and by a tubercle to the transverse processes; but as they extend backwards the head disappears, and the ribs are attached only to the extremities of the transverse processes.

In the *Balænidæ* the first pair of ribs are remarkable for their great breadth, especially at the sternal extremity, and these alone join the sternum. In the *Balæna Capensis* the two first, as well as the four last pairs of ribs, are joined only to the transverse processes of the vertebræ.

The depressors and elevators of the ribs appear to possess nothing particular, and the same may be said of the diaphragm and the muscles of the abdomen; but in regard to the movements of these parts, we must remember what M. Mayer says of the muscular fibres, which encircle closely the lungs, and which take part in the actions of inspiration and expiration.

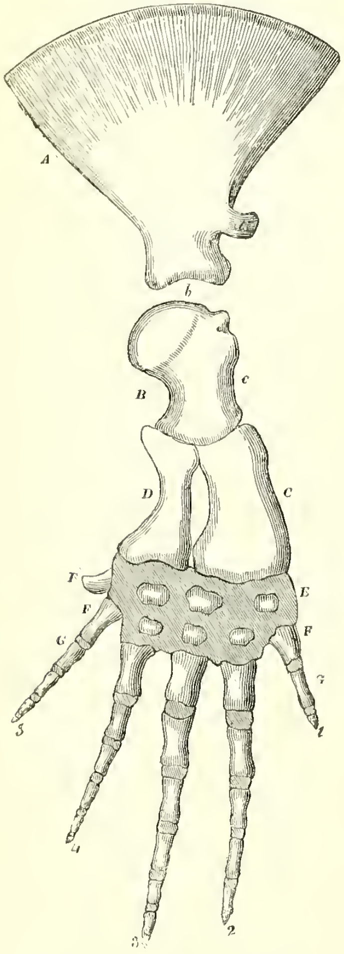
[Mr. Hunter observes that, " as the ribs in this tribe do not completely form the cavity of the thorax, the diaphragm has not the same attachments as in the Quadruped, but is connected forwards to the abdominal muscles, which are very strong, being a mixture of muscular and tendinous parts. The position of the diaphragm is less transverse than in the Quadruped, passing more obliquely backward and coming very low on the spine, and high up before, which makes the chest longest in the direction of the animal at the back, and gives room for the lungs to be continued along the spine."]

The anterior members in the Cetaceans do not essentially differ from those of the other Mammalia, but they undergo, in these animals, very great modifications.

In the shoulder they are entirely devoid of clavicles. Their scapula is very large in general, but varies in this respect according to the species. In the Herbivorous Cetaceans, as the Dugong (*s*, *fig* 246), the anterior angle is rounded, the posterior is extended backwards, and the posterior margin or costa is concave. The spine is prominent, and so placed as to divide the dorsum of the scapula into a supra-spinal and infra-spinal depression. The acromion is pointed, but much less elongated in the Dugong than in the Manatee. The coracoid process is also more pointed in the Dugong.

In the Zoophagous Cetaceans the spine of the scapula does not project much. The supra-spinal fossa is reduced to a mere groove in the common Dolphin, and entirely disappears in the Gangetic species (*Platanista*); the coracoïd process does not exist in this last dolphin; and the same absence is found in the *Balænidæ*, whilst it is seen in the common Dolphin and the Cachalot. Lastly, the acromion appears always to exist, but with a different development, in different species. In the scapula of the Whalebone Whale (*A*, *fig*. 255) it is marked *a*. The articular or

Fig. 255.



Bones of the anterior fin of a Whale, Balæna Mysticetus.

glenoid cavity (*b*) is proportionally larger in this species than in the Spermaceti Whale. The muscles of this part of the anterior member present some remarkable modifications, but with which we are only acquainted as they exist in the common Dolphin. Thus the serratus magnus does not extend as far as the cervical vertebræ, and ends at the ribs; the *pectoralis minor*, instead of descending on the ribs, is directed towards the anterior extremity of the sternum.

The *rhomboideus* (*a*, *fig*. 256) is not attached to the ridge of the spine, but extends along the superior edge of the scapula; the *trapezius* covers the scapula and has no clavicular prolongation.

The *levator scapulæ* (*b*, *fig*. 256) is attached to the broad transverse process of the first vertebra, and spreads itself over all the external surface of the scapula.

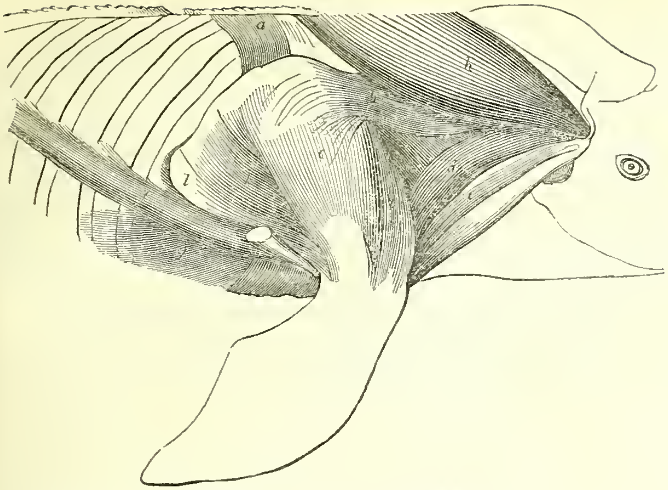
The rest of the anterior member is composed of the humerus, the radius, the carpus, the metacarpus, and the phalanges.

In the Dugong the humerus (*t*, *fig*. 246) is much shorter and thicker than in the Manatee, and the deltoid ridge is more prominent. In the true Cetacea the humerus is always very short. In the Whalebone Whale (*B*, *fig*. 255) its length is scarcely double its breadth; its head is hemispherical and almost parallel to the axis of the bone. The lower extremity is divided into two planes slightly inclined for the ulna and radius.

The cubitus and the radius (*v*) are also very short, and are anchylosed (*u*, *fig*. 246) together at both extremities in the Manatee and the Dugong, but they retain in these Cetaceans the rounded form which is peculiar to them in the other Mammalia. In the spouting Cetaceans they are compressed, and are united by means of fibro-cartilage with the humerus and the carpus. The olecranon varies in size. In the great Whale it rises in but a small degree, while in the Spermaceti Whale it is developed in the form of a hook. The radius (*C*, *fig*. 255), which is broader than the ulna (*D*, *fig*. 255), is dilated at its lower extremity.

The bones of the carpus are very much flattened, and of an hexagonal form; they are less in number than in Man, but the number varies according to the species. The Manatee has six, the pisiform being wanting. The Dugong has four (*w*, *fig*. 246), of which two are in the first row corresponding respectively to the radius and ulna, and two in the second row, the external one supporting the metacarpal bones of the pollex and index, the internal bone supporting the medius and annularis; the ulnar or little digit is supported by the ulnar carpal bones of both the first and second row. The pollex (*x*, *fig*. 246) is reduced, as in the Manatee, to a small pointed metacarpal bone. The common Dolphin has only five metacarpal bones; the Whale has seven: of these four are in the first row, and three in the second (*E*, *fig*. 255). The metacarpals (*F*, *fig*. 255) are five in number, much flattened, and have the general form of phalanges. The phalanges in the Zoophagous Cetaceans partake of the flattened form of the bones of the metacarpus. Their number increases in each finger, comparatively with the normal number, sometimes very much so; and in many cases there are some which remain cartilaginous. The pollex (*G* 1, *fig*. 255) in the great Whale has two bones; the index

Fig. 256.



Muscles of the anterior fin of a Dolphin.

a. Rhomboideus.
b. Levator scapulæ.
c. Infra-spinatus.
d. Humero-mastoideus.
e. Sterno-mastoideus.
f. Costo-humeralis or latissimus dorsi.
g. Portion of pectoral.
h. Splenius.

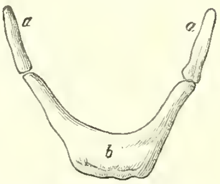
(2) four, the digitus medius (3) five, the annularis (4) four, and the digitus parvus (5) three bones; all are terminated by a cartilaginous dilatation: they form collectively a large and short paddle, obliquely rounded.

The muscles which characterize the arm of the Mammalia exist generally also in the Dolphin, and doubtless in the other Cetaceans, but with modifications which have not been so satisfactorily described as could be wished. The great pectoral muscle (a part of which is seen at *g*, *fig*. 256) presents the sternal portion, which is called the *musculus communis*, or muscle common to the two arms. The *latissimus dorsi* (*f*, *fig*. 256) is represented by a little muscle, the digitations of which are attached to the ribs; the *supra-spinatus* and *infra-spinatus* are nearly of equal size, but the subscapularis is very large. The *coraco-brachialis* is very short. The muscles of the other parts of the arm, that is, of the fore-arm and hand, appear in a rudimental state, and seem to exist less on account of the movements of the parts to which they are attached, than to shew the analogy of the anterior members of the Cetaceans with those of other Mammalia.

[In our dissections of the common Porpesse we have found the supra-spinalis of small size, corresponding to the size of the supra-spinal fossa. It is covered by the deltoid muscle (*i*). The *infra-spinatus* (*c*) is consequently of much larger size, but is a thinner muscle: behind this muscle is seen the teres *major* (*k*) and *minor* (*l*).]

As we have already said, the posterior extremities are wanting; all that remains of them are the rudiments of a pelvis. These rudiments are found in the Dugong to be composed of two pairs of bones (*y*, *fig*. 246) united two and two, and end to end by a cartilage, and attached by a cartilage also to one of the vertebræ. In the Dolphins they consist of two little, long, thin bones which are lodged in the flesh, one to the right and the other to the left of the anus. In the Whales, at the extremity of each of these bones (*a*, *a*, *fig* 257), which are regarded as ilia, a second (*b*) is found articulated, smaller, and curved; the convexity of which is external, and might represent a pubis, or an ischion; it seems to correspond to the second of these bones in the Dugong.

Fig. 257.



Pelvis of the Mysticete Whale.

We perceive that the internal construction of the organs of movement in the Cetaceans does not vary in the different species except by modifications the importance of which we are not able to appreciate. The differences in their exterior structure, moreover, do not appear to exercise any influence over their mode of living; for the chief of these consists in the Manatee having nails to the ends of its pectoral fin, which correspond to the fingers, of which it is in part composed; and in its tail being oval instead of being extended laterally into two wings.

We have in no way considered as forming part of the organs of movement, the protuberances which are seen upon the back of some species of spouting Cetaceans, sometimes in the form of a bump, and sometimes like a fin, more or less elevated. These protuberances, in fact, are nothing more than simple gibbosities, simple prolongations of the skin, filled with dense cellular tissue and fat, and resembling more or less a fin, but devoid of any independent movement, and without any direct connection either with the vertebræ of the back or with the muscular system.

Digestive organs. — The alimentary apparatus is one of those, which, in many of its parts, presents the most important modifications in the Cetaceous Order.

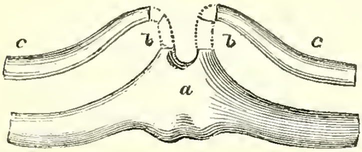
The three genera into which the Herbivorous Cetaceans are divided, are characterized by three systems of dentition fundamentally different. The Manatees have *molares* with double or triple ridges, and with the root distinct from the crown, presenting a remarkable resemblance to those of some of the Pachyderms, as the Hippopotamus. The Dugongs have simple elliptical *molares*, the crown of which, before it is worn, presents two slight furrows, which are entirely effaced by age. They are without fangs, properly so called; and in the upper jaw are found two long tusks, of which the other Cetaceans of this family are destitute. The *Rytinæ* have no molares at all; these teeth are replaced by a horny plate in the middle of each jaw, a structure which seems to connect these animals with the Whalebone Whales.

The *tongue* is short and but little susceptible of movement.

The os hyoides is characterized in the Cetacea chiefly by the slight degree or total absence of connection with the larynx, resulting from the elevated position of this organ required by its peculiar relations with the posterior nares.

In the Herbivorous order the Dugong presents a simple form of the os hyoides; the posterior cornua soon anchylose with the body, but send no ligament to the thyroid cartilage. The anterior cornua generally remain cartilaginous, and form the medium of union between the body or basi-hyal, and the large and long styloid processes. In the *Delphinidæ* the body and posterior cornua of the hyoid bone are of a flattened form. In the *Balænidæ*, as the Piked Whale or Balænoptera, the body (*a*, *fig.* 258) is a cylindrical bone, extended

Fig. 258.

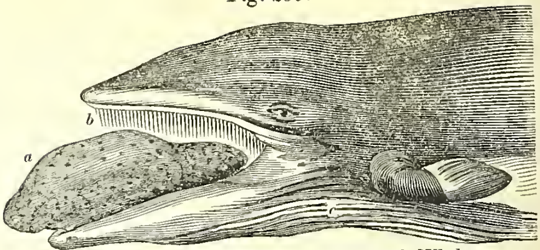


Hyoid bones of the Piked Whale.

transversely, and is slightly curved backwards and upwards; its middle portion supports anteriorly two processes (*b*, *b*) resembling the base of the anterior cornua in the Ruminants; besides these there are, in this genus, two rounded tubercles on the posterior margin opposite these processes. The styloid bones (*c*, *c*) are cylindrical and slightly curved in two directions; they are joined by cartilage on each side to the occipital protuberance which represents the mastoid process.

The muscles which protrude and retract the tongue are extremely simplified in the Cetaceans; the retractors are represented by a single pair, analogous to the stylo-hyoidei, the fibres of which pass from the posterior margin of the stylo-hyal bones to the body of the hyoid. The stylo-glossi pass from the anterior and superior margin of the styloid process to their insertion. The hyoglossi arise from the middle of the convexity of the os hyoides.

Fig. 259.

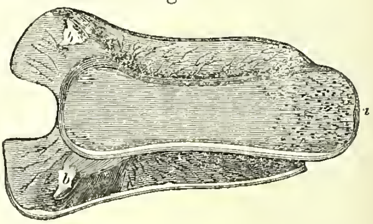


*Tongue and Baleen-plates of the Piked Whale, Balænoptera Boops.**

The genio-glossi pass backwards and inwards from the anterior contour of the lower jaw.

The tongue itself corresponds to the form of the space included by the rami of the lower jaw, and is consequently of great size in the Cachalots and Balænidæ, rising in the latter like an immense cushion (*a*, *fig.* 259), into the space between the laminæ of baleen (*b*), and affording a great quantity of the finest oil. In the figure it is represented in the Piked Whale, but probably preternaturally enlarged and raised by the extrication of gas caused by putrefaction. It is thick, and its free extremity is generally short, but this is less remarkable in the *Phytophaga* than in the *Zoophaga*. In the Dugong (*fig.* 260) the upper surface of the anterior part of the tongue (*a*) is beset with cuticular spines, and on each side of its basis there is a remarkable horny retroverted pointed process (*b*, *b*).

Fig. 260.



Tongue of the Dugong.

In the Porpesse the surface of the tongue is soft and smooth, and very flat superiorly; the anterior margin is fringed by a number of short irregular processes (*a*, *fig.* 265).

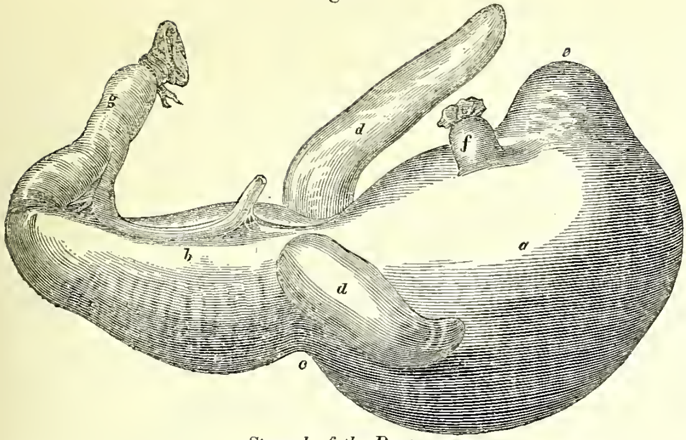
The salivary glands are reduced to the most rudimental condition.

In the Phytophagous Cetaceans the stomach is separated into two portions (*fig.* 261); one, the cardiac (*a*), very large, the other, the pyloric (*b*), of narrower calibre, by a contraction (*c*) giving origin to two prolongations (*d*, *d*), which are tubiform in the Dugongs, and of a pouch-like form in the Manatees.

In both species there is a gland at the cardiac extremity of the stomach (*c*), which in the Dugong, Sir Everard Home (from whose memoir the figure subjoined is taken) describes as "forming a round mass, as in the Beaver. The orifices of these glands are small, and

* From Fr. Cuvier, *Cetacea*, pl. 20.

Fig. 261.

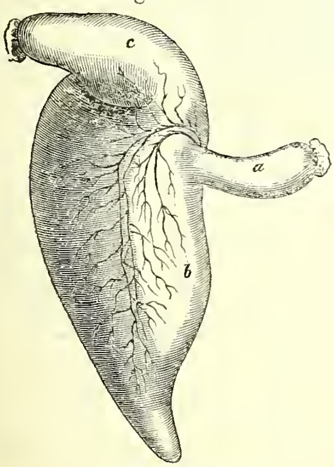


Stomach of the Dugong.

covered over with a membranous bag, which has only one large aperture. The glandular mass is divided into two portions."* Thus the stomach of the Dugong presents peculiarities which are met with singly in animals of the Cetaceous, Pachydermatous, and Rodent Orders. Like the stomach of the Whale it is divided into distinct compartments; like the stomachs of the Hippopotamus and Peccary it has cœcal pouches superadded to and communicating with it; and like those of the Dormouse and Beaver its cardiac compartment is provided with a glandular apparatus: (*f* is the œsophagus, *g* the intestine.)

The cœcum is simple and cordiform in the Dugong (*fig.* 262), but is of more irregular

Fig. 262.



Cœcum of the Dugong.

figure and bifurcated in the Manatee. The *Rytina* appears also to possess a stomach divided into two portions, of which the cardiac is also larger than the pyloric; and it has a very large cœcum, divided on its internal surface into numerous cells. A gland, remarkable for its size, is also found in the first portion of the stomach of this species. No substances but *fuci* have ever been found in the alimentary canals of these animals.

The Zoophagous Cetaceans present still greater differences in their alimentary organs than the *Phytophaga*. In the Dolphins the teeth, which are generally simple and conical, or compressed in both jaws, vary considerably in number, and often remain concealed in a rudimentary state in the gums. In the Cachalots they are only found in the lower jaw; are simple and oviform; and their number appears to be in no way certain. The Whales have no true teeth, but at each side of their palate grow, transversely, horny plates, named baleen (the whalebone of commerce), provided on their inner edges with fringe-like beards, amidst which, as in the meshes of a net, the animals which form their food are retained.

[The structure, forms, and disposition of the teeth having been given in the characters of the different genera of Cetacea, we have here only to add a few words on the subject of the baleen-plates which form their substitutes in the family of Balænidæ. Each of these plates consists of a central, coarse, fibrous, and two exterior or lateral compact layers; the first extends beyond the latter, so that the plate terminates at its lower or free extremity in a fringe, and in looking upwards into the mouth of a Whale when all the baleen-plates are in situ, only their fringed extremities are seen.

The base of each baleen-plate has a conical cavity, which is fixed upon a pulp of a corresponding form, buried deeply in the firm vascular substance of the gum which covers the under surface of the maxillary and intermaxillary bones; the sides of the base of the baleen-plate are firmly attached to white horny laminæ of the gum, which are reflected from one plate to another, and from which the external compact layers of the baleen are continued: the pulp appears to be subservient to the secretion of the central coarse fibrous part alone.]

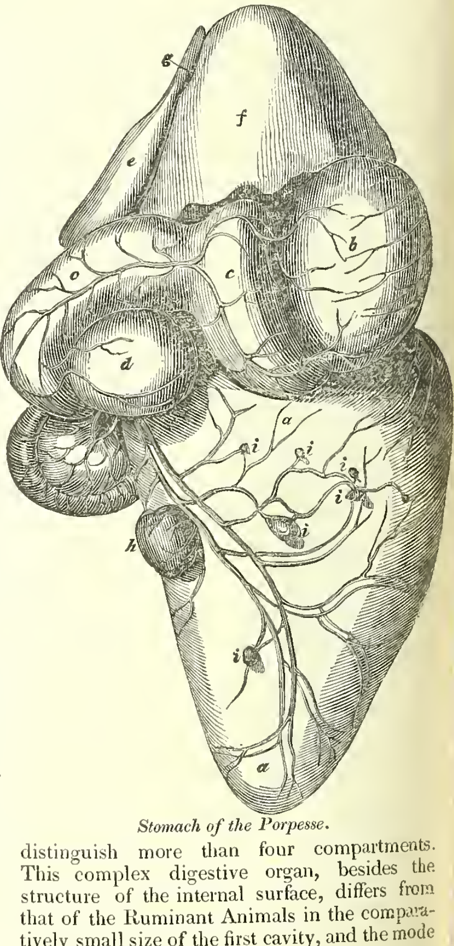
Nothing can differ more, or indeed be more contradictory than the descriptions which have been given of the stomachs of the Zoophagous Cetaceans. In many of the species the structure of this part is unknown. It has been more or less fully described in the *Delphinorhynchus micropterus*, the common Dolphin, the Small Bottle-nose (*Delphinus Tursio*), the common Porpoise, the Grampus, the

* Phil. Trans. 1820, p. 317.

Phocæna globiceps, the carinated Porpoise, the Béluga, the Platanist, the Narwhal, the Great Bottle-nose or Hyperoodon, and the Piked Whale (*Balænoptera*). There is no doubt that the stomachs of all these animals are very complicated; and although it may be more than probable that they do not resemble each other in their composition, it is to be presumed, however, that it is to their complication we must attribute the essentially different descriptions which have been put forth on this subject. What authorizes this supposition is the diversity of opinions which exists relative to the number of the stomachs of the common Dolphin and common Porpoise, some counting only three, others four, others five, and others six, &c. Now it is certain that these differences of number proceed simply from the manner in which this organ is viewed. When it is only judged of by its exterior, and its globulous parts alone are called stomach, only three or four can be reckoned; and then the more or less tubular passages, situated amongst those more or less spherical cavities, are considered as mere intercommunicating canals. But if the interior of these stomachs be studied, it is seen that several amongst them have a special organization, and are separated from one another by small openings, which do not invariably establish a direct communication between them: hence the tubular parts cannot be considered as simple passages, but must necessarily be admitted as essential parts of the stomach, which, like the others, impress their peculiar action upon the food. It has also been the case that the dilated sac into which the biliary and pancreatic juices are poured, has not been admitted as belonging to the stomach; but besides its not being without example that in Mammalia the bile may be poured immediately into the stomach, the difference in the nature of the membranes ought to suffice for deciding whether the part which receives these secretions belongs or not to the duodenum. Now in the Dolphins it is evidently at the termination of the last stomach that their duct opens. In this state of things it is impossible to decide with precision in what particulars the Zoophagous Cetaceans differ from one another in the structure of the stomach. It appears, however, that this organ in the common Dolphin, the common Porpoise, the *Globiceps*, and the Platanist, is formed upon the same type, and is composed of five parts; and if they differ one from another, it is only by modifications of secondary importance. If to these facts we add what Meckel states respecting the Narwhal, in which he recognizes five stomachs, and what Hunter says of the Grampus and Piked Whale, in which he likewise found five, we have three species more to add to the first. In fact, when we consider that only three or four stomachs have been recognized in the Carinated Porpesse and the Beluga, which are true *Phocænæ*, and that Baussard saw three, and Hunter seven in the Hyperoodon (Great Bottle-nose Whale), we believe ourselves authorized in thinking that these differences depend entirely upon the manner in which this organ is viewed, and we consider it very probable that the number of stomachs in these Cetaceans, as in the others, is five. However, from this small number of facts, and from all the conjectures with which we have been obliged to approach the subject, we shall draw no precise conclusion as to the structure which may be common to the Zoophagous Cetaceans. But this undoubted great complication of the stomach in animals which are nourished with the most animalized food, is an anomaly the cause of which it would be very important to investigate; for from the ascertained facts which we have to reason from, we are not led by any analogy to an explanation of this subject.

[In our examinations of the stomach of the Porpesse (*fig.* 263), we have not been able to

Fig. 263.



Stomach of the Porpesse.

distinguish more than four compartments. This complex digestive organ, besides the structure of the internal surface, differs from that of the Ruminant Animals in the comparatively small size of the first cavity, and the mode of inter-communication of the other compartments, which succeed one another, and are not appended to the extremity of the œsophagus: instead, therefore, of the œsophagus communicating with all the four cavities, it opens only into the first, and consequently no rumination can take place. The first cavity is continued in the same line with the œsophagus, having the same structure, and not being divided from it by any sensible constriction; its commencement is indicated by the orifice leading into the second stomach, beyond which orifice it is continued in the form of a dilated ovate cavity *(a)*. It is lined with a cuticle, and its inner surface is beset with small rugæ. A number of large irregular projections surround the aperture leading to the second cavity, and are calculated to prevent the passage into the second of any substances save such as are of very small size. Notwithstanding the nature of the lining membrane the digestive processes are considerably advanced in this cavity, which does not act simply as a reservoir. It is probable that the secretion of the second stomach, which is highly glandular, regurgitates into the first and assists in producing the dissolution of the carneous parts of the fishes, the remains of which are usually found in it. The thick cuticular lining terminates abruptly at the small orifice leading into the second stomach *(b)*. The interior of this cavity presents a series of close-set thick longitudinal wavy rugæ, laterally indented into one another. The internal layer is thick and of a peculiar structure: according to Sir David Brewster, " it seems, in its wet state, to consist of tubes or fibres perpendicular to the two membranes which inclose them, and the upper surface of one of the membranes is covered with hollows or depressions corresponding with the extremities of the tubes or fibres. A more minute examination, conducted in a different way, proves these perpendicular portions to be tubes. In order to dry it, I pressed it between folds of paper, and the effect of the compression was to press together nearly all the tubes, and make the whole one dense mass, of a dark brown colour; but when it became dry and slightly indurated, I drew it out as if it had been India-rubber, and the tubes opened, and the mass became white."

The membrane next the cavity of the stomach is perfectly smooth; the one external to the fibres is a vascular and cellular tunic, and is inverted by the layer of muscular fibres continued from the preceding cavity. The communication with the third stomach is near the lower end of this cavity. The third compartment is a small round vascular cavity, into which the second opens obliquely: it is lined by a smooth and simple villous tunic. It is not visible exteriorly, and does not exceed an inch in length in the Porpesse, but in the *Hyperoodon* is about five inches long. The fourth cavity *(c, c)* is long and narrow, and passes in a serpentine course almost like an intestine; the internal surface is smooth and even, but villous. It opens on the right side into the duodenum (*d*), which is much dilated, and, as in the human subject, is without valvulæ conniventes at its commencement. The pylorus is a smaller opening than that between the third and fourth cavities.]

Some authors speak affirmatively of a considerable bladder, which in the Rorquals, after death, comes up into the mouth and forces the two jaws asunder. Now what is the nature of this vesicular mass, of which other authors say nothing? To what organic system does it belong? This has never been made a subject of enquiry. It has been considered as belonging to the respiratory system, or as an air-bladder analogous to that of fish. Is it not more probably a portion of the stomach distended by the gases formed there?

In general the Spouting Whales have no cœcum. However, a trace of this gut has been found in an oval elevation in the Platanist; a cœcum exists also in the Piked Whale and in the Whale-bone Whale. The variations in form or affinity of the spleen and the liver appear to have no essential relation with the forms of the stomach.

[Mr. Hunter observes that " there is a considerable degree of uniformity in the liver in this tribe of animals. In shape it nearly resembles the human, but is not so thick at its base nor so sharp at the lower edge, and is probably not so firm in its texture. The right lobe (*e*, *fig*. 263) is the largest and thickest, its falciform ligament broad, and there is a large fissure (*g*) between the two lobes, in which the round ligament passes. The liver towards the left *(f)* is very much attached to the stomach, the little epiploon being a thick substance. There is no gall-bladder." " The pancreas is a very long, flat body, having its left end attached to the right side of the first cavity of the stomach: it passes across the spine at the root of the mesentery, and near to the pylorus joins the hollow curve of the duodenum, along which it is continued, and adheres to the intestine, its duct entering that of the liver near the termination of the gut."—*Phil. Trans.* 1787, p. 410.

The structure of the biliary organs has a closer resemblance to that of Quadrupeds in the Herbivorous Cetacea, and differs from that above described in the presence of a gall-bladder, besides some minor points.

In the Dugong the liver is a transversely-oblong viscus, divided into three lobes with a fourth small process at the root of the left lobe, representing the lobulus Spigelii. It is as usual convex towards the diaphragm, but rather flattened than concave towards the viscera, the anterior margin thick and rounded. Of the three larger lobes the middle one is the smallest, of a square shape, projecting forward, and as it were overhanging the gall-bladder, which is lodged in the middle of the inferior surface. The ligamentum suspensorium is continued upon the middle lobe, immediately above the gall-bladder, the anterior margin of this lobe being notched to receive it, and the remains of the umbilical vein entering the liver an inch above the fundus of the gall-bladder. The two lateral lobes are more than double the size of the cystic lobe, and of these the left is the largest. Both these lobes are concave towards the small middle lobe, which they thus surround and conceal. The lobulus Spigelii is of a flattened and square shape, measuring one inch and a quarter in length and one inch in breadth. The gall-bladder is of an elongated form, about an inch in diameter at the broadest part. It does not receive the bile by means of a communication between the cystic and hepatic ducts as in most animals, but that fluid is conveyed directly into it by two distinct hepato-cystic canals in the same manner and situation as the ureters terminate in the urinary bladder. The two orifices are half an inch apart on the same transverse line, and at a distance of three inches from the *fundus vesicæ* they are large, readily admitting a full-sized probe. The common ducts, of which they are the terminations, are half an inch in length, and branch off into the lobes on either side. The inner membrane of the gall-bladder is rugous; it has a longer investment of peritoneum than in man. Where it ends it is difficult to say, as it gradually diminishes in size after the entry of the above ducts, and does not appear to be separated from the cystic duct by any marked contraction or valvular structure. The cystic duct is about six inches in length, and two lines in diameter; dilates a little before entering the duodenum, and as it passes between the coats of that intestine the canal is provided with a reticular valvular structure of the inner membrane, which may probably supply the deficiency of this structure in the preceding parts of the duct.

Three *venæ cavæ hepaticæ* from the three lobes of the liver join the vena cava inferior at the upper and posterior edge of the liver, which is not, however, perforated by it as in most quadrupeds. The *vena portæ*, formed in the usual manner, but deriving a very small branch from the spleen, enters the fissure below the gall-bladder.

Sir Everard Home takes no notice of the pancreas; Sir Stamford Raffles merely observes that it lay 'below the duodenum.' It is situated below and behind the pyloric cavity of the stomach. Its length in a Dugong six feet long we found to be seven inches; it was obtuse and thick at the splenic or left end, where its diameter was two inches, and gradually growing smaller towards the duodenum, it terminated in one uncommonly large duct, which was three lines in diameter and of great length. On laying open this canal the orifices of from twenty to thirty tributary ducts were observable, which were two lines in diameter; the coats of these ducts thick, and terminating in flattened lobules.

The spleen, as Sir S. Raffles observes, was very small, of a rounded form; its length in the larger specimen four inches and a half, its breadth in the middle one inch and a half, from which it tapered to either end; its structure finely reticular.

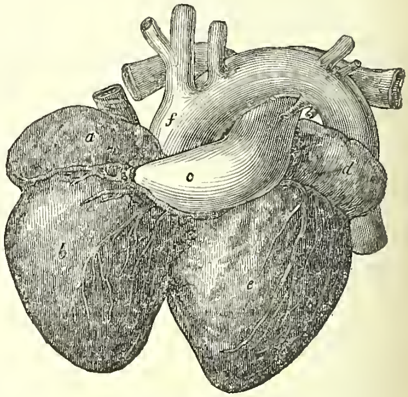
In the Piked Whale the spleen is single and of small proportional size; in the Porpesse this organ is remarkable for its subdivision into distinct portions, of which one is generally about the size of a walnut (*h*, *fig.* 263); the others, to the number of four, five, or six (*i*, *i*), are of much smaller size.]

The Spouting Whales always feed upon living food. The Dolphins and Cachalots pursue or catch fish principally, and large Mollusks, whilst Whales prey upon the numerous little Molluscous and articulated animals and Vermes which swarm, it is said, in the northern seas, and in the number of which are reckoned crustaceans, cuttle-fishes, clios, medusas, sea-anemonies, &c; but in this respect a difference must be made between the Balænopteræ and the Whales, properly so called (*Balænæ*), for we are assured that the first also feed upon fish, and are capable of swallowing much larger animals than the latter.

Organs of Circulation.—The researches of the anatomist on the circulating system of the Cetaceans have not hitherto been extended to many species. In its essential parts it is similar to that in other Mammalia. But the peculiar nature of Cetaceans, and the great modifications of their organs of movement, have necessarily produced in this system, not only modifications analogous to those of these organs, but vascular developments exclusively characteristic of these animals.

It is not known whether the Manatee presents anything particular in regard to the organs of circulation, but the heart of the Dugong (*fig.* 264) and of the Rytina is cloven by the

Fig. 264.



Heart of the Dugong.

deep separation of the two ventricles, a circumstance which adds an important link of affinity to those already subsisting between these animals.

[In the heart of the Dugong, the ventricles, as Sir Stamford Raffles has correctly described them,* are not completely detached from one another. The auricles are of equal size and of a rounded form. In the right auricle (*a*), which receives a single superior cava, the coronary vein, and the inferior cava, there is on the auricular side of the orifice of the latter vein a fleshy Eustachian valve, of the size and form which, in such cases, is commonly seen in the human subject. The valve of the foramen ovale has a reticulate surface at the upper margin, but is entire and imperforate. The right ventricle (*b*), in the Du-

* Phil. Trans. 1820, p. 174.

gong previously mentioned, which was six feet in length, was three inches and a half long and three inches broad at the base; the thickness of its parietes one line and a half; the carneæ columnæ are few, and resemble those in man. The tricuspid and mitral valves are of the usual form and structure, but the latter are broader than in man, measuring each one inch three lines across the base. The diameter of the orifice of the pulmonary artery (*c*) is one inch and a half. The capacity of this vessel is very great, according with the impediments to the transmission of blood through the lungs which must arise from the submarine habits of this animal. In the left auricle (*d*) the transverse pectinated muscular bands are equally if not more developed than in the right. The trace of the foramen ovale is more evident on this side the *septum auriculare* than in the right auricle; it appeared as an oblique slit directed upwards, about three lines broad, but was completely closed.

The parietes of the left ventricle (*e*) are half an inch in thickness; there is nothing unusual in the mitral valve or the carneæ columnæ connected with it; the inner surface of the ventricle was as usual smooth below the origin of the aorta (*f*). The breadth of the semilunar valves here was ten lines, the diameter of the orifice being one-third less than that of the pulmonary artery. The ductus arteriosus was completely obliterated.]

The heart in the Dolphins and Whales does not appear to have undergone any remarkable modifications; but their arterial system presents a very important one in the infinite circumvolutions of arteries, and the vast plexuses of vessels, filled with oxygenated blood, which are found particularly under the pleura and between the ribs, on each side of the spine.

[Of this remarkable structure, which was discovered by Hunter, we here subjoin the original description.

" The general structure of the arteries resembles that of other animals; and where parts are nearly similar, the distribution is likewise similar. The aorta forms its usual curve, and sends off the carotid and subclavian arteries.

" Animals of this (the Whale) tribe, as has been observed, have a greater proportion of blood than any other known, and there are many arteries apparently intended as reservoirs, where a larger quantity of arterial blood seemed to be required in a part, and vascularity could not be the only object. Thus we find, that the intercostal arteries divide into a vast number of branches, which run in a serpentine course between the pleura, ribs, and their muscles, making a thick substance somewhat similar to that formed by the spermatic artery in the Bull. Those vessels, every where lining the sides of the thorax, pass in between the ribs near their articulation, and also behind the ligamentous attachment of the ribs, and anastomose with each other. The medulla spinalis is surrounded with a net-work of arteries in the same manner, more especially where it comes out from the brain, where a thick substance is formed by their ramifications and convolutions; and these vessels most probably anastomose with those of the thorax.

" The subclavian artery in the Piked Whale, before it passes over the first rib, sends down into the chest arteries which assist in forming the plexus on the inside of the ribs; I am not certain but the internal mammary arteries contribute to form the anterior part of this plexus. The motion of the blood in such cases must be very slow; the use of which we do not readily see. The descending aorta sends off the intercostals, which are very large, and gives branches to this plexus; and when it has reached the abdomen it sends off, as in the quadruped, the different branches to the viscera and the lumbar arteries, which are likewise very large, for the supply of that vast mass of muscles which moves the tail.

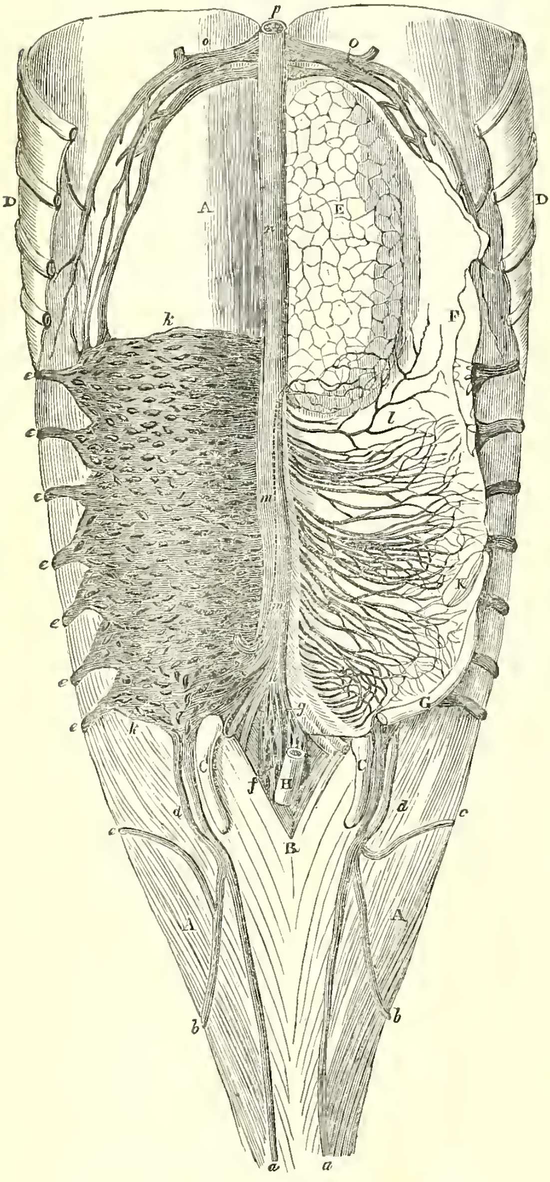
" In our examination of particular parts, the size of which is generally regulated by that of the whole animal, if we have only been accustomed to see them in those which are small or middle-sized, we behold them with astonishment in animals so far exceeding the common bulk as the Whale. Thus the heart and aorta of the Spermaceti Whale appeared prodigious, being too large to be contained in a wide tub, the aorta measuring a foot in diameter. When we consider these as applied to the circulation, and figure to ourselves that probably ten or fifteen gallons of blood are thrown out at one stroke, and moved with an immense velocity through a tube of a foot diameter, the whole idea fills the mind with wonder."*]

It is to be presumed, as has been done, that this singular complication of vessels is caused by the necessity in which the Cetaceans are often placed of suspending their respiration, and consequently the oxygenation of their blood, during a considerable time. These numeerous arteries form, therefore, a reservoir of oxygenated blood, which, re-entering the circulation, supports life throughout, where venous blood would only produce death. But how this blood is sent to this general system of arteries, or what is the peculiar force which acts upon it to this effect, is a point on which we are still reduced to the most vague conjectures.

* Phil. Trans. 1787. p. 415. It must be supposed that M. Breschet, who has recently written on the arterial plexuses of the Cetacea, could only have known the preceding description by extract or reference, or he would not have stated that the structure in question had been 'observée par J. Hunter, mais indiquées trop sommairement pour pouvoir être des lors comptés au nombre des faits acquis à la science,' for we do not find in M. Breschet's paper any essential addition to the original account given by our celebrated anatomist, either with respect to the observation of additional facts, to their clearer description, or to the physiological inferences deduced from them. It is agreeable to find that M. V. Baer, whose observations on the subdivision of the brachial arteries, and on other parts of the vascular system of the Porpesse, are real additions to the anatomical history of the Cetacea, by no means considers it necessary to depreciate the value of the observations of his predecessors in the same field of enquiry.

The disappearance of the posterior members has occasioned that of the vessels which should nourish those members; and as the tail has attained a considerable development, the arteries and veins which belong to this last part of the trunk have been developed in the same proportion. The abdominal aorta does not send off any external iliacs, but is continued underneath the tail in the canal of the inferior processes, from whence its ramifications are distributed to the muscles which move this organ. The modifications of the venous system are in many respects analogous to those of the arteries.

Fig. 266.



Abdominal venous plexus and kidney of the Porpesse.

The quantity of blood contained in the vascular system appears to be proportionally much greater than in the other Mammalia.

[In the Porpesse the veins are almost universally devoid of valves, so that they can be as easily injected from trunks to branches, as in the reverse direction. The plexiform disposition which we have seen to characterize so many parts of the arterial system is still more strongly displayed in the venous. Thus in the system of the anterior vena cava, with the exception of the trunk of that vein itself, and the short jugular veins which join it, an internal and an external jugular branch, and a pair of large subcutaneous veins, all the other parts of the system manifest the plexiform disposition. This is most remarkable in the large venous sinuses surrounding the central axis of the nervous system, which receives the intercostal veins, and by means of which the system of the anterior cava is chiefly brought into communication with that of the posterior cava; for, as V. Baer has observed, there is no intercommunicating channel analogous to the vena azygos of the higher Mammalia.

Of the venous plexuses belonging to the system of the inferior cava, that which is found at the posterior parietes of the abdominal cavity extending from below the kidney to the lower boundary of the abdomen is the most remarkable, and we have selected in illustration of this, the figure from Baer's excellent memoir on the vascular system of the Cetacea.* In this figure (*fig.* 266) the anterior parietes of the abdomen are removed. The two immense lateral depressor muscles of the tail are seen at *A*, *A*, and *B* shows their point of convergence to be inserted into the inferior spinous processes, by which the cavity of the abdomen is contracted and defined posteriorly. Just anterior to this commissure is seen the termination of the rectum *H*. *C*, *C*, are the two ischia. *D*, *D*, the posterior parietes of the chest projecting forwards over the abdomen. On the right side the kidney and the peritoneum are removed; on the left side they are seen *in situ*, and also a part of the left cornu of the uterus *G*, with the oviduct and ovary *K*.

At *p* is seen the inferior vena cava cut through, which lies in the interspace of the two great depressors of the tail. The trunk of the vena cava seems smaller than it

* Ueber das Gefass - system des Braunfisches, Nova Acta, Phys. Med. Leopold. Carol. tom. xvii. 1835.

really is, on account of its deep position and the overlapping of the kidney, *E*. As it gets beyond this part it is seen to dilate. Two veins, corresponding to the *venæ iliacæ* of Quadrupeds, (*m, m*,) return the blood in part to the tail, and join the vena cava near the kidneys. The vein corresponding to the caudal or sacro-median of Quadrupeds is not a simple vessel, but a plexus, which is surrounded and protected by the inferior spinous processes; it is seen at *f*. A venous plexus from the intestinal canal (*g*) terminates in the right iliac vein, which is larger than the left, and thus establishes a communication between it and the portal system. *h* shows a muscular vein, and *i* the termination of a hypogastric plexus.

The more important plexuses which communicate with the iliac veins are, first, the peritoneal plexus (*l*), which in older individuals, and especially at the season of sexual excitement, is much more considerable than is here represented; and secondly, the iliac or psoadic plexus (*k, k*), which forms an immense reservoir of venous blood. It is situated between the under surface of the depressors of the tail, which represent the psoas muscles, and the peritoneum, reaching from behind the lower extremity of the kidney to the posterior end of the abdomen, and forming a mass of closely interwoven veins, of an inch or more in thickness, and serving to bring the subcutaneous veins of the posterior part of the body into communication with the posterior vena cava.

This plexus is fed, if we may use the expression, by *a*, an inferior vein; *b*, a lateral; and *c*, a superior vein of the tail, which unite to form an ischiadic sub-plexus, *d*. Laterally the iliac plexus receives from five to seven veins, which return the blood from the dorsal and lateral parietes of the abdomen, and pierce the lateral abdominal muscles to join the plexus at *e, e*. On its internal or mesial edge the iliac plexus communicates by many and wide apertures with the iliac vein. At the anterior part of the abdomen the inferior cava receives the plexus phrenicus, *o, o*.

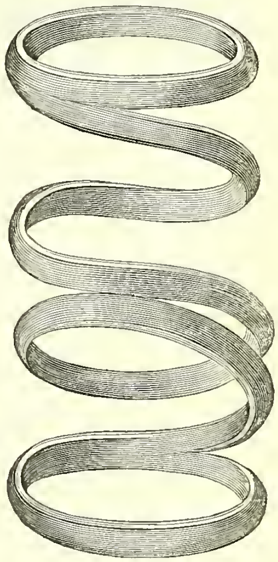
The condition of the venous system above described, while it is admirably adapted to the mode and sphere of existence of the Cetaceans, presents a beautiful instance of that co-ordinate analogy to the condition of the veins in the embryo of the higher Mammals, which is exhibited in the general form of the animals composing this the lowest order of the class.]

Organs of Respiration.—The organs and all the essential phenomena of respiration are the same in the Cetaceans as in the other Mammals. They have been made the subject of but few observations.

[In the Dugong the lungs are of a very elongated and flattened form, resembling those which Daubenton has figured of the Manatee. They are, as Sir Everard Home has observed, one-fourth the length of the animal; those from the animal, eight feet long, which he received from Sir Stamford Raffles, measuring two feet. They are convex posteriorly or on the dorsal aspect, flattened on the opposite side, and along this surface the principal branches of the bronchi can be seen through the serous covering. The upper end of each lung is obtuse, thick, and narrow; they gradually become flatter towards the lower extremity, the margin of which is rounded.

The whole surface of these lungs presents an appearance somewhat similar to that of the Turtle (*Chelonia Mydas*), in consequence of the large size of the superficial air-cells, which are a line in diameter (*a, a, fig.* 268.) The great extent of the lungs down the back, and the high division of the trachea, and consequent length of the bronchi, are further instances of this resemblance.

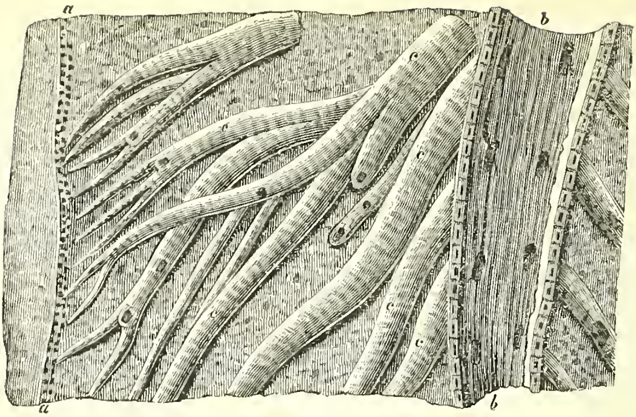
Fig. 267.



Cartilages of the bronchus of the Dugong.

The cartilages of the bronchial tubes are continued spirally into one another (*fig.* 267): the pulmonary artery lies to the outer side of the bronchus and is deeper seated; the pulmonary vein to the inner side, and is superficially situated. The principal branch of the bronchus (*b, fig.* 268) runs down near the inner margin of the lung, and continues distinct to within four inches of the end; it then divides into smaller branches; the larger ramifications are given off from its outer side, *c, c*. In all the branches the cartilaginous rings continue distinct and strong till their diameter is contracted to one or two lines; the rings passing irregularly into each other as in the main trunks. The lining membrane of the air-tubes is thrown into longitudinal rugæ, indicating their dilatability. We have before mentioned the large size of the pulmonary artery: in this respect, as well as in the structure of the lung, the Dugong manifests a greater similarity to the reptile than the Porpoise docs. In this animal the air-cells in no part of the lung exceed a sixth part of the size of the superficial ones in the Dugong; and

Fig. 268.



Structure of the lung of the Dugong.

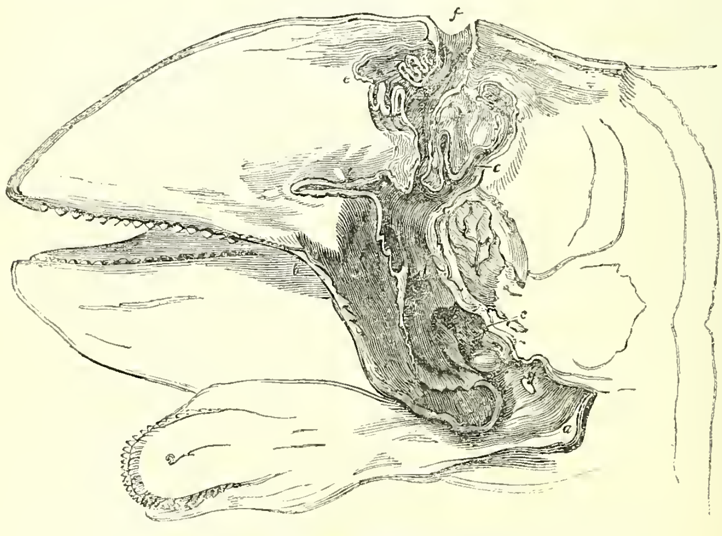
the pulmonary artery is proportionally smaller. From the difference that exists in the locomotive habits of the two animals arising from the difference in the nature of the food, may be deduced the circumstances which relate to the difference in the respiratory organ. The Porpoise, ever bounding and gambolling on the surface, breathes as it were at will; whilst the Dugong is compelled to prolonged submersion in order to acquire its food, which from its fixed attachment, and comparatively innutritious nature, necessarily demands much time in collecting.]

It is said that, in the Dolphins, each lung is surrounded by muscular fibres, which take part also in the acts of inspiration and expiration, and that the lobes communicate with each other in such a manner that, air being introduced through one of the bronchi alone, they are all filled with it.

But though the diaphragm, the lungs, the bronchi, and the trachea are only found with modifications of a secondary order, the nostrils, which serve intermediately for the passage of the air, between the atmosphere and the respiratory organ, present very important ones. It is especially upon these modifications that the exterior distinction between the Herbivorous and the Spouting Whales depends. In the structure of the nostrils, the mechanism by which the phenomenon of the spouting is produced has necessarily caused some changes, which, on the one hand, appear to have necessitated the exclusion of the organ of smell, and, on the other, to have led to the formation of a new organ entirely peculiar to this order of Mammalia.

We may be allowed to believe that this organ is essentially the same in the Dolphins, the Cachalots, and the Whales; it has only,

Fig. 269.



Vertical section, shewing the tongue, larynx, and nostrils of the Porpesse.

however, been studied with any detail in the Dolphins, and its principal parts consist in the larynx, which ascends as far as the posterior nares; in the disposition of the muscles of the pharynx, which have the power of binding the anterior part of the respiratory organ; and in the membranous and fleshy bags placed at the superior part of the nostrils.

The orifice of the spouting hole, which is simple in the Dolphins, is situated towards the summit of the head (*f*, *fig.* 269); in the Cachalots it is equally simple, and situated at the superior extremity of the snout; and in the Whales it is double, and opens towards the summit of the head, as in the Dolphins, under the form of a crescent, the convexity of which is sometimes forward and sometimes backward.

In the Herbivorous Cetaceans, the orifice of the nostrils is found, in the Manatee at the anterior extremity, and in the Dugong at the middle and upper part of the snout.

[We here subjoin the detailed description of the spouting apparatus of the Porpesse, from the pen of Baron Cuvier. "If we trace the œsophagus upwards, we find that when it arrives opposite the pharynx (*a*, *fig.* 269), it appears to divide into two passages, of which one (*b*) is continued onwards to the mouth, while the other (*c*) mounts to the nose: this latter passage is surrounded with mucous glands and fleshy fibres which constitute several muscles. Some of these are longitudinal, arising from the circumference of the posterior orifice of the bony nostrils, and descending along that canal to the pharynx and its lateral parts; the others are annular and seem to be a continuation of the proper muscle of the pharynx; as the larynx rises into this passage in the form of an obelisk or pyramid, these annular fibres have the power of grasping it by their contractions.

"All this part is provided with mucous follicles which pour out their secretion by conspicuous excretory orifices. The lining membrane of the nasal passage having reached the vomer (*d*), assumes a peculiar texture; it becomes thin, smooth, and of a black colour, is apparently destitute of vessels and nerves, and is very dry.

"The two osseous nasal canals are closed at the superior or external orifice by a fleshy valve in the form of two semicircles, attached to the anterior margin of that orifice, which it closes by means of a very strong muscle lodged above the intermaxillary bones. In order to open it, some foreign body must press against it from below. When this valve is closed, it cuts off all communication between the nasal passages and the cavities above them. These cavities are two large membranous pouches (*e*, *e*), formed by a dark-coloured mucous skin, much wrinkled when they are empty; but assuming, when distended, an oval figure, which, in the Porpesse, equals the capacity of a wine-glass. These two pouches are lodged beneath the integument, in front of the nostrils; they communicate with an intermediate space immediately above the nostrils, which open externally by a transverse semilunar slit. Very strong fleshy fibres form an expansion, which covers all the upper surface of this apparatus; these fibres radiate from the entire circumference of the cranium to unite above the two pouches, and are adapted to compress them forcibly. Let us suppose the Cetacean has taken into its mouth some water which it wishes to eject: it moves its tongue and jaws as if it were about to swallow it; but, closing its pharynx, it forces the water to mount into the nasal passages, where its progress is accelerated by annular fibres, until it raises the valve and distends the membranous pouches above. Once in the pouches, the water can be retained there until the animal wishes to spout. For that purpose, it closes the valve to prevent the descent of the water into the nasal passages, and it forcibly compresses the pouches by means of the muscular expansions which cover them: compelled then to escape by the narrow crescentic aperture, it is projected to a height corresponding to the force of the pressure."

Urinary organs.—The Phytophagous Cetaceans are not distinguished by a form and structure of the kidney different from that in the Zoophagous tribes; for, although in the Dugong the kidney has an uniform unbroken external surface, yet in the genus *Rytina*, according to Steller, that organ is subdivided into a great number of lobules, as in the Seal and Sea-Otter, and consequently resembles in this respect the typical or true Cetacea. Hunter makes the same statement with respect to the Manatee.*

In the Dugong the tubuli uriniferi terminate by two lateral series of eleven mammillæ in a single elongated pelvis, from which the ureter is continued. In the Porpesse and Whale there is no common pelvis, but the ureter commences by more than two hundred branches from as many distinct lobes or renules, of the aggregate of which the entire kidney is formed (*E*, *fig.* 266). Each renule is of a conical figure, having its base towards the circumference, and its apex towards the centre of the kidney; it is composed of a cortical and medullary substance, the latter terminating in a single mammilla at the apex, where it is surrounded by a long infundibulum, wide at its commencement, where it embraces the base of the mammilla, and thence becoming smaller, and uniting with others to form the common excretory duct.

Müller found that each of the lobules of the kidney in the fœtus of the Dolphin consisted principally of the convoluted uriniferous ducts extending from the apex to the periphery of the lobule, the intertwinings of the tubuli being greatest in the cortical part (*fig.* 270).

It is a curious fact that the supra-renal gland in the Porpesse presents a certain resemblance to the kidney in its lobulated exterior; but the analogy extends no farther, for on making a section of this part, it is seen to be composed of the usual continuous compact substance.]

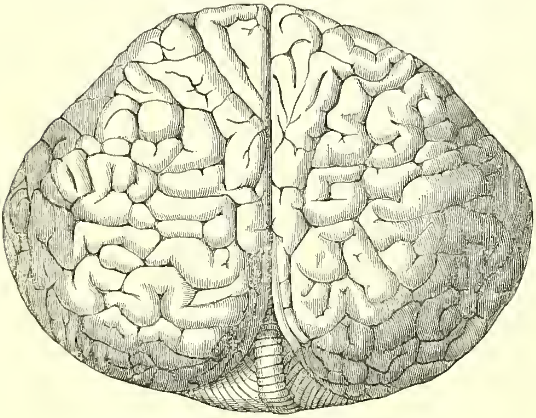
* In the paper on Whales, p. 412.

Fig. 270.

A section of one of the lobes or renules of the kidney of a Dolphin.

The Nervous System.—The nervous system, like the greater part of the other organic systems, has in many species of the *Cetacea* been the subject only of superficial observations. Formed on the plan of that of Mammalia in general, it has followed in its development that of the other organs, in all cases in which it was naturally dependent on such modifications. Thus the lumbar and sacral nerves do not give origin to those of abdominal members, whilst, on the other hand, the coccygeal nerves are found numerous and powerful. The olfactory nerves do not exist, unless, as some authors say, it is in the form of almost imperceptible threads. What appears certain is, that in the common Dolphin, and in the common Porpesse there are no traces of ethmoïdal openings; and if there are holes in the ethmoïd of the Whale, they are in very small number, and nothing proves that they give passage to nerves.* In the common Dolphin and Porpesse, the brain is found as richly developed as in any Mammiferous quadruped whatever.

Fig. 271.

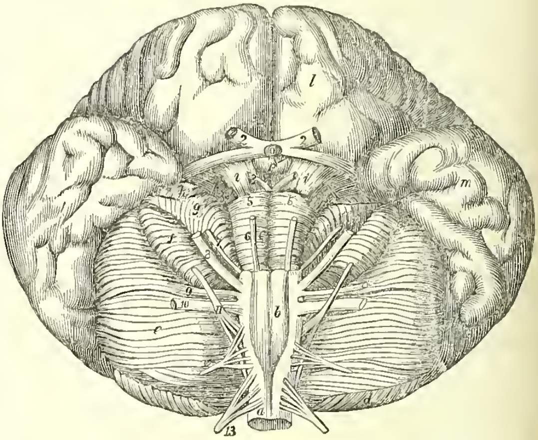


Brain of the Dolphin, Delphinus Delphis.

To judge from the capaciousness of the skull, the other species of this family of Cetacea have not been less liberally gifted than the common Dolphin. The brain of the Cachalots and the Whales has not been made a subject of study, or has been so only in a very superficial way. To judge of it by the cranial cavity, one may conclude that in them this organ is reduced to very small dimensions.

[The illustrations of the brain of the Cetacea (*fig.* 271, 272, 273) are taken from the excellent figures of the brain of the Dolphin (*Delphinus Delphis*), published by Tiedemann in the second volume of his *Zeitschrift für Physiologie*, (*pl.* xii. p. 251.) The following description embodies the observations of the same author on the brain of the Dolphin, and of Hunter on that of the *Balænoptera* (Piked Whale). In a young specimen of the *Balæna rostrata*, which measured seventeen feet, Hunter

Fig. 272.



Base of the brain of a Dolphin, Delphinus Delphis.

found that the brain weighed four pounds eight ounces. In a young *Balæna mysticetus* nineteen feet long, Scoresby found the weight of the brain to be three pounds twelve ounces. From analogy we may suppose that the brain had here acquired nearly its full development, which gives us, taking the weight of the full grown whale at 11,200 pounds, the ratio of the weight of the brain to that of the body as $\frac{1}{3000}$. In the smaller Cetacea, however, the brain is not diminished to a proportionate size, but exhibits a development which may be said to be extraordinary, even in the Dolphin of six feet in length.

In tracing the brain according to Tiedemann's method from below upwards, we first observe the

* M. F. Cuvier seems here to have overlooked the fact that Hunter had established the existence of an organ of smell in the Balænidæ. He observes, "In many of this (the Whale) tribe, there is no organ of smell at all; and in those which have such an organ, it is not that of a Fish, therefore

spinal chord (*a*, *fig*. 272) gently expanding into the medulla oblongata, on the anterior surface of which the *corpora pyramidalia* (*b*, *fig*. 272) are seen well defined and prominent. At the point where they begin to rise above the surface of the medulla, there is a manifest decussation of their internal fibres; they proceed through the *pons Varoli* (*c*), aud are continued into the crura cerebri.

The *corpora olivaria* are situated near the *pyramidalia;* they do not, however, project from the surface as in the human brain, but are distinguishable by the internal grey substance (*corpus dentatum olivæ*). Their medullary fibres proceed through the pons and enter the bigeminal bodies, in which they converge and decussate each other.

The transverse medullary fibres, which are seen in most Mammalia extending across the under surface of the medulla oblongata immediately behind the pons, and which Treviranus has called the *trapezium*, are wanting in the brain of the Dolphin, as in that of the Orang Utan and the Human subject.

The two posterior columns of the spinal chord are continued (according to Tiedemann) as the *corpora restiformia* to the cerebellum. Between these is situated the fourth ventricle, from the floor of which the acoustic nerves take their origin.

The very large size of the cerebellum in proportion to the spinal chord and cerebrum, which Hunter noticed in the Piked Whale, is equally remarkable in the Dolphin. The cerebellum is deeply divided into lobes, of which six may be distinguished on the upper surface of each hemisphere. Of these, two small lobes correspond to the posterior superior lobes of the human cerebellum.

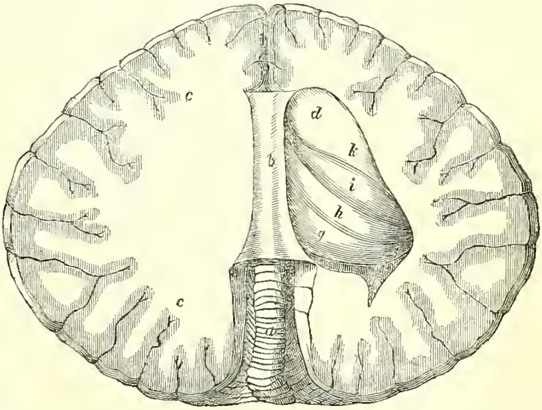
On the under surface we remark the posterior inferior lobes (*e*), the anterior inferior lobes (*f*), one lobe corresponding to the amygdaloid lobe of Reil (*g*), and the *floccus* (*h*). Each lobe is subdivided by deep fissures into smaller lobes, and these again by shallow anfractuosities into lamellæ. The middle or vermiform portion of the cerebellum (*a*, *fig*. 273) is not symmetrical, but inclined, like the cranium itself, to the right side. The internal medullary substance of the cerebellum resulting from the divergent fibres of the *crus*, *corpus restiforme*, and *processus ad testes*, and the superadded commissural fibres, has a well-marked internal grey substance or *corpus fimbriatum*, and is covered by the usual external layer of similar material. Between the columns which extend from the cerebellum to the bigeminal bodies, the medullary lamella called valvula Vieussenii is situated. The pons or commissure of the cerebellum (*c*, *fig*. 272) is of large size, corresponding to the hemispheres of the part which it seems to associate in action.

The cerebrum is extended backwards over the cerebellum, but the posterior parts of the hemispheres diverge from one another so as to expose a part of the cerebellum. The most striking feature of the cerebrum is its great breadth, which exceeds its length, a disposition of this organ peculiar among Mammalia to the Cetaceous order. Each hemisphere is seen at its inferior surface to be divided by the *fissura magna* (*k*, *fig*. 272) into an anterior (*l*) and middle lobe (*m*), which latter is continued above the cerebellum into the posterior lobe. The whole external surface of the hemispheres is divided by deep anfractuosities into convolutions, which are proportionally more numerous and narrower even than in the human brain. This structure seems common to all the Cetacea; besides the observations of Tiedemann and Cuvier in the common Dolphin, the numerous convolutions have been remarked by Tyson in the brain of the Porpesse, and by Scoresby in that of the Mysticete Whale.

The crura cerebri (*i*, *fig*. 272) are of large size; the eminentiæ mammillares (*p*) are as usual situated between them, and anterior to these are the infundibulum and pituitary gland (*o*).

The two hemispheres in the Dolphin's brain described by Tiedemann, measured each two inches and eleven and a half lines in length, and were united by a corpus callosum (*b*, *fig*. 273,) of one inch and three lines in length. The chief peculiarity of this part is its position, which is not horizontal, but inclined downwards and forwards. The bigeminal bodies are of considerable size; the anterior ones are rounded and lie closer together than the posterior. These have an oval form, and are separated by a depression which receives the

Fig. 273.



probably not calculated to smell water. It becomes difficult therefore to account for the manner in which such animals smell the water; and why the others should not have had such an organ, which seems to be peculiar to the large and small Whalebone Whales (*Balæna mysticetus* and *Balænoptera rostrata*); the organ, in those which have it, is extremely small, when compared with that of other animals, as well as the nerve, which is to receive the impression."—Phil. Trans. pp. 428, 430.

anterior part of the vermiform process of the cerebellum.

The pineal gland is a small flattened body about two lines in length, connected as usual to the *thalami optici*. These appear in each ventricle in the form of an oval flattened body (*i*, *fig*. 273). They are joined together posteriorly by the medullary commissure. Tiedemann did not observe any soft commissure.

The third ventricle is continued anteriorly into the infundibulum.

The *corpora striata* (*d*) are proportionally of small size, as Hunter observed in the brain of the Whale. They are united anteriorly by the anterior commissure.

The *fornix* is also of inconsiderable size. The slender anterior pillars of the fornix proceed to the mammillary bodies, and send forwards two small triangular medullary lamellæ to the under surface of the anterior part of the corpus striatum, from which the septum lucidum is continued. The fornix then bends backwards along the under surface of the corpus callosum and above the thalami, and its hinder crura sink down, diverging from each other to form the cornua ammonis (*g*). These bodies are small, thin, but broad, and exhibited no denticulated folds. The tænia fimbriata (*h*) are attached as usual to the external border of the cornua.

The lateral ventricles are capacious though short; they extend, as in the human brain, into an anterior, a middle, and a posterior horn; the latter, however, is very small. In each ventricle there is a large plexus choroides, which is remarkable for the transverse parallel folds of membrane which support the divisions of the artery.

With respect to the cerebral nerves, Tiedemann states that, although in the Dolphin the brain was removed with every precaution from the skull, yet he could not perceive the slightest trace of the olfactory pair. Hunter and Tyson equally failed to detect them in the Porpesse. Treviranus, however, believed that with the aid of a magnifying glass he had detected very delicate filaments in the situation of the olfactory nerves in the Porpesse. But supposing that there was no illusion here, which could hardly have happened to so accurate and close an observer, these fibres represent only a very rudimental condition of the olfactory nerves; and we may observe that the shortness of the anterior lobes of the brain, and the smallness of the striated bodies are closely related to the absence or imperfect development of the first pair of nerves.

With respect to the other cerebral nerves, they are relatively larger in proportion to the brain than in man. The optic nerves (2, *fig*. 272) rise partly from the thalami, partly from the anterior bigeminal bodies and the corpora geniculata; they curve round the crura cerebri, and unite as usual before the pituitary gland. The angle at which the nerves diverge from each other after the decussation is more open than in other Mammalia.

The accessory nerves of the eye are of large size, as the third (3), the fourth (4), and the sixth (6) pair.

The fifth pair (5), which emerge from the sides of the pons, but arise from the medulla oblongata between the corpora restiformia and olivaria, have a smaller proportional size than in man.

The nerves concerned in the actions of respiration, as the facial (7), the pneumogastric (10), and the recurrent (11), are well developed, in relation to the large size of the muscles which effect the respiratory movements in the dense medium of water.

The glosso-pharyngeal nerve (9) and the lingual (12) are also very large, corresponding to the vigorous associated actions of the tongue and pharynx, which must take place during deglutition in the Cetacea.

But perhaps the most remarkable nerve for its great relative size is the acoustic (8), which certainly testifies to the delicate sense of hearing in the Dolphins.]

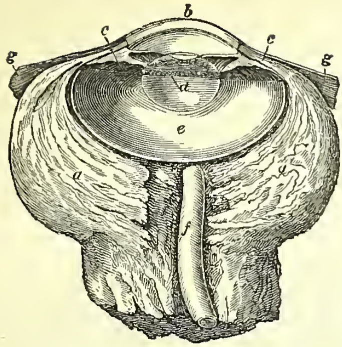
The organs of the senses, with the exception of that of smell, are composed, in all the Cetaceans, of the parts which essentially constitute them in terrestrial Mammalia, and are only modified with reference to the habitually aquatic life of the animals of this order. But little inquiry has been made as to their utility in these animals, the length of time they continue serviceable, and the characteristic differences which might be drawn from them for the distinction of the species.

Eye.—The eye of the Herbivorous Cetaceans alone is provided with a lateral lid or membrana nictitans; that of the Spouting Whales is devoid of lachrymal glands; but its lids are furnished below with little glands which secrete a mucous matter, adapted like the tears for lubricating the sclerotica.

[Hunter observes that "the eye in this tribe of animals is constructed upon nearly the same principle as that of quadrupeds, differing, however, in some circumstances; by which it is probably better adapted to see in the medium through which the light is to pass. It is upon the whole small for the size of the animal, which would lead to the supposition that their locomotion is not great; for, I believe, animals that swim are in this respect similar to those that fly; and as this tribe come to the surface of the medium in which they live, they may be considered in the same view with birds which soar; and we find, birds that fly to great heights, and move through a considerable space, in search of food, have their eyes larger in proportion to their size.

"The eyelids have but little motion, and do not consist of loose cellular membrane, as in quadrupeds, but rather of the common adipose membrane of the body; the connexion, however, of their circumference with the common integuments is loose, the cellular membrane being less loaded with oil, which allows of a slight fold being made upon the surrounding parts in opening the eyelids. This is not to an equal degree in them all, being less so in the Porpoise than in the Piked Whale.

Fig. 274.



Section of the eye of a Whale.

" The tunica conjunctiva *(g, g, fig.* 274), where it is reflected from the eyelid to the eyeball, is perforated all round by small orifices of the ducts of a circle of glandular bodies lying behind it.

" The lachrymal gland* is small, its use being supplied by those above-mentioned; and the secretion from them all, I believe to be a mucus similar to what is found in the Turtle and Crocodile. There are neither puncta nor lachrymal duct *(ductus ad nasum)*, so that the secretion, whatever it be, is washed off into the water.

" The muscles which open the eyelids are very strong; they take their origin from the head, round the optic nerve, which in some requires their being very long, and are so broad as almost to make one circular muscle round the whole of the interior straight muscles of the eye itself. They may be divided into four; a superior, an inferior, and one at each angle; as they pass outwards to the eyelids, they diverge and become broader, and are inserted into the inside of the eyelids almost equally all round. They may be termed the dilatores of the eyelids; and, before they reach their insertion, give off the external straight muscles, which are small, and inserted into the sclerotic coat before the transverse axis of the eye; these may be named the elevator, depressor, adductor, and abductor, and may be dissected away from the others as distinct muscles. Besides these four going from the muscles of the eyelid to the eye itself, there are two which are larger, and enclose the optic nerve with the plexus. As these pass outwards they become broad, may in some be divided into four, and are inserted into the sclerotic coat, almost all round the eye, rather behind its transverse axis.

" The two oblique muscles are very long; they pass through the muscles of the eyelids, are continued on to the globe of the eye, between the two sets of straight muscles, and at their insertions are very broad: a circumstance which gives great variation to the motion of the eye.

" The sclerotic coat (*a, a, fig.* 274) gives shape to the eye, both externally and internally, as in other animals; but the external shape and that of the internal cavity are very dissimilar, arising from the great difference in the thickness of this coat in different parts. The external figure is round, except that it is a little flattened forwards; but that of the cavity is far otherwise, being made up of sections of various circles, being a little lengthened from the inner side to the outer, a transverse section making a short ellipsis.

" In the Piked Whale *(Balænoptera rostrata)* the long axis is two inches and three quarters, the short axis two inches and one-eighth.

" The posterior part of the cavity is a tolerably regular curve, answering to the difference in the two axises; but forwards, near the cornea, the sclerotic coat turns quickly in, to meet the cornea, which makes this part of the cavity extremely flat, and renders the distance between the anterior part of the sclerotic coat and the bottom of the eye not above an inch and a quarter.

" In the Piked Whale the sclerotic coat, at its posterior part, is very thick: near the extreme of the short axis it was half an inch, and at the long axis one-eight of an inch thick. In the Bottle-nose Whale *(Hyperoodon)*, the extreme of the short axis was half an inch thick, and the extremes of the long axis about a quarter of an inch, or half the other.

" The sclerotic coat becomes thinner as it approaches to its union with the cornea, where it is thin and soft. It is extremely firm in its texture where thick, and from a transverse section would seem to be composed of tendinous fibres, intermixed with something like cartilage; in this section four passages for vessels remain open. This firmness of texture precludes all effect of the straight muscles on the globe of the eye by altering its shape, and adapting its focus to different distances of objects, as has been supposed to be the case in the human eye.

" The cornea (*b, fig.* 274) makes rather a longer ellipsis than the ball of the eye; the side of which are not equally curved, the pp being most considerably so. It is a segmen. of a circle somewhat smaller than that of the eyeball, is soft and very flaccid.*

" The tunica choroides resembles that of the quadruped; and its inner surface is of a silver hue, without any nigrum pigmentum. The pigmentum nigrum only covers the ciliary processes (*c, c*), and lines the inside of the iris. The retina (*e*) appears to be nearly similar to that of the quadruped.

" The arteries going to the coats of the eye form a plexus passing round the optic nerve, resembling in its appearance that of the spermatic artery in the Bull and some other animals.

* This is analogous rather to the Harderian gland, being situated at the inner or nasal side of the eyeball.

* Its laminated texture is well displayed in the Whale; Leeuwenhoek counted twenty-two layers.

"The crystalline humour (*d*) resembles that of the quadruped; but whether it is very convex or flattened, I cannot determine; those I have examined having been kept too long to preserve their exact shape and size. The vitreous humour adheres to the retina at the entrance of the optic nerve. The optic nerve (*f*) is very long in some species, owing to the vast width of the head."*

The crystalline lens is of a spherical form, but slightly flattened anteriorly: it is inclosed in a strong and dense capsule, and is placed at a very small distance from the cornea, so that it diminishes the space for the aqueous humour, while it increases that for the vitreous; this exists in a greater degree than is shown in the subjoined figure, as Soemmering, from whose work 'De oculorum sectione horizontali' the figure is taken, himself allows. From the peculiar colour and eccentric position of the nucleus of the lens in the Whale's eye, in which it is of a dark colour, and placed in the posterior half of the lens, we are led to suspect that the section of the lens in Soemmering's plate is imaginary.]

Ear.—The ear is without any external concha; no doubt a sphincter has the office of closing the entrance of the auditory canal, to preserve the tympanum, which some call fibrous, and others cartilaginous, from the contact of the water. The Eustachian tube exists according to some anatomists, others deny it. The senses of sight and hearing, notwithstanding their apparent imperfection, appear to be endued with great delicacy. Whale-catchers assert that Whales, Cachalots, &c. see and hear at a great distance, and that, in order to approach them, many precautions are necessary; otherwise these animals would avoid them by a sudden retreat, and it would become necessary to recommence the long and laborious chase. We ought, nevertheless, to add that Scoresby, who speaks of the delicacy of hearing of the Whales, states that they remain insensible to the noise of the report of a cannon.

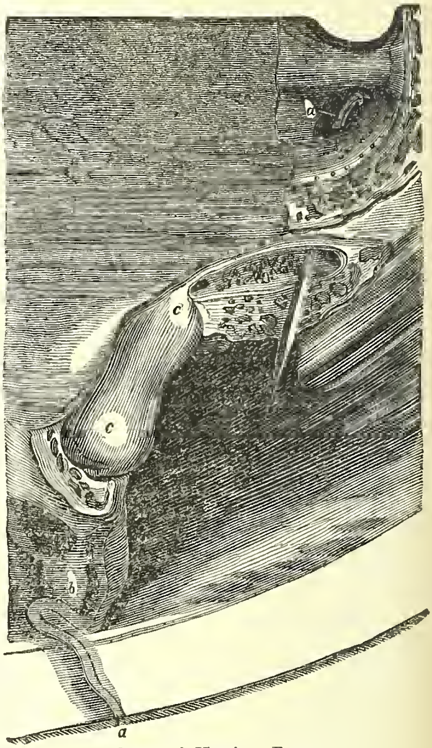
[For the most accurate and philosophical description of the Organ of Hearing in the present tribe we again recur to Hunter's admirable paper on the organization of the Cetacea. He observes, that "the ear is constructed much upon the same principle as in the quadruped; but as it differs in several respects, which it is necessary to particularize, to convey a perfect idea of it the whole should be described. As this would exceed the limits of this paper, I shall content myself with a general description, taking notice of those material points in which it differs from that of the quadruped.

"This organ consists of the same parts as in the quadruped; an external opening, with a membrana tympani, and Eustachian tube, a tympanum with its processes, and the small bones.

"There is no external projection forming a funnel, but merely an external opening. We can easily assign a reason why there should be no projecting ear, as it would interfere with progressive motion; but the reason why it is not formed as in birds, is not so evident; whether the percussions of water could be collected into one point as air, I cannot say. The tympanum is constructed with irregularities, so much like those of an external ear, that I could suppose it to have a similar effect.

"The external opening begins by a small hole, (*a*, *fig.* 275), scarcely perceptible, situated on

Fig. 275.



Organ of Hearing, Porpesse.

the side of the head a little behind the eye. It is much longer than in other animals, in consequence of the size of the head being so much increased beyond the cavity that contains the brain. It passes in a serpentine course (*b*), at first horizontally, then downwards, and afterwards horizontally again, to the membrana tympani, where it terminates. In its whole length it is composed of different cartilages, which are irregular and united together by cellular membrane, so as to admit of motion, and probably of lengthening or shortening, as the animal is more or less fat.

"The bony part of the organ (*c*, *c*) is not so much inclosed in the bones of the skull as in the quadruped, consisting commonly of a distinct bone or bones, closely attached to the skull, but in general readily to be separated from it; yet in some it sends off, from the posterior part, processes which unite with the skull. It varies in its shape, and is composed of the im-

* Philos. Trans. 1787, p. 440.

mediate organ (or labyrinth) and the tympanum.

"The immediate organ is, in point of situation to that of the tympanum, superior and internal, as in the quadruped. The tympanum is open at the anterior end, where the Eustachian tube begins.

"The Eustachian tube opens on the outside of the upper part of the fauces: in some higher in the nose than others; highest, I believe, in the Porpoise. From the cavity of the tympanum, where it is rather largest, it passes forwards and inwards, and near its termination appears very much fasciculated, as if glandular. (A probe passes through the Eustachian tube in the figure, showing its nasal termination at *d*.)

"The Eustachian tube and tympanum communicate with several sinuses, which passing in various directions surround the bone of the ear. Some of these are cellular, similar to the cells of the mastoid process in the human subject, although not bony. There is a portion of this cellular structure of a particular kind, being white, ligamentous, and each part rather rounded than having flat sides.*

"One of the sinuses passing out of the tympanum close to the membrana tympani, goes a little way in the same direction, and communicates with a number of cells.

"The whole function of the Eustachian tube is perhaps not known; but it is evidently a duct from the cavity of the ear, or a passage for the mucus of these parts; the external opening having a particular form would incline us to believe, that something was conveyed to the tympanum.

"The bony part of the organ is very hard and brittle, rendering it even difficult to be cut with a saw, without its chipping into pieces. That part which contains the immediate organ is by much the hardest, and has a very small portion of animal substance in it; for when steeped in an acid, what remains is very soft, almost like a jelly, and laminated. The bone is not only harder in its substance, but there is on the whole more solid bone than in the corresponding parts of quadrupeds, it being thick and massy.

"The part containing the tympanum is a thin bone, coiled upon itself, attached by one end to the portion which contains the organ; and this attachment in some is by close contact only, as in the Narwhale; in others, the bones run into one another, as in the Bottle-nose and Piked Whales (*Hyperoodon* and *Balænoptera*).

"The concave side of the tympanum is turned towards the organ, its two edges being close to it; the outer is irregular, and in many only in contact, as in the Porpoise: while in others the union is by bony continuity, as in the Bottle-nose Whale (*Hyperoodon*), leaving a passage on which the membrana tympani is stretched, and another opening, which is the communication with the sinuses.

"The surface of the bone containing the immediate organ (the petrous bone, *p*, *fig.* 269) opposite to the mouth of the tympanum is very irregular, having a number of eminences and cavities."

According to the Baron Cuvier* the petrous bone in the *Delphinidæ* is permanently lodged between the temporal and contiguous parts of the occipital bone; it forms the upper and inner part; the tympanum the lower and outer. The petrous bone is brittle and very thick. It has a larger portion, an irregular ellipsoid, which gives attachment to the tympanum by its outer surface, and which contains the three semicircular canals; and another smaller portion in the form of a quarter of a sphere, which is separated from the first by a pretty deep depression, and is occupied internally by the cochlea. The acoustic nerves enter by foramina at the bottom of the depression.

The tympanum is formed by a thick bony plate folded longitudinally, so as to form a canal, open anteriorly, whence is continued the Eustachian tube. It is closed behind, where it assumes a bilobate figure, and adheres above this part to the outer and posterior part of the petrous bone by a rough process, which is firmly wedged in, but does not anchylose soon. It adheres to it also by a part of the external margin, and it is between these two points of adhesion that we find the very irregular opening of the tympanum. The internal margin leaves a long interval between it and the petrous bone. Beneath the bilobate portion of the tympanum the styloid process passes, which is attached immediately behind it by ligaments to the descending plate, which represents the mastoid process.

The bone of the ear of the Cachalot displays great relations with that of the Dolphins, only the tympanum is shorter and less lobated behind.

The bone of the ear in the *Balænidæ* differs from that of the *Delphinidæ* by the enormous thickness of the tympanum (*a*, *fig.* 276), especially at the inner side. This tympanum is a little more closed anteriorly, but leaves between it and the *os petrosum* (*b*) on the inner side a proportionally shorter and wider interspace. It is not bilobed posteriorly.

The petrous bone is of a very irregular shape and knotty surface; it gives off two large rough processes, of which one is situated behind and a little above, and articulates with a corresponding process of the tympanum, is wedged between the temporal and lateral occipital bones; and the other, situated anteriorly and below, is articulated by a squamous suture with the part of the temporal which descends to furnish the articulation of the lower jaw. This second process, which in the *Balænæ* is as large as the other, is very small in the *Balænoptera*; nevertheless the ear-bone of the Balænæ is fixed more solidly to the cranium than that of the *Delphini*.

* "These communications with the Eustachian tube may be compared to a large bag on the bases of the skull of the Horse and Ass, which is a lateral swell of the membranous part of the tube, and when distended will contain nearly a quart."

* Oss. Foss. vol. v. pt. i. p. 300.

A comparison of the ear-bone of *Balæna Australis* with that of *Balæna Mysticetus* corroborates by differences, slight indeed, the distinction of species between them.

"The cavity of the tympanum (*a, a, fig.* 276) is lined with a membrane, which also covers the small bones with their muscles, and appears to have a thin cuticle. This membrane renders the bones, muscles, tendons, &c. very obscure, which are seen distinctly when that is removed. It appears to be a continuation of the periosteum, and the only uniting substance between the small bones. Besides the general lining, there is a plexus of vessels, which is thin and rather broad, and attached by one edge, the rest being loose in the cavity of the tympanum, somewhat like the plexus choroides in the ventricles of the brain. The cavity, we may suppose, intended to increase sound, probably by the vibration of the bone; and from its particular formation we can easily conceive that the vibrations are conducted, or reflected, towards the immediate organ, it being in some degree a substitute for the external ear.

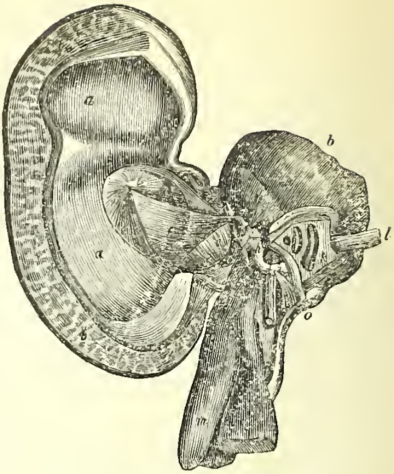
"The external opening being smaller than in any animals of the same size, the membrana tympani is nearly in the same proportion. In the Bottle-nose Whale, the Grampus, and Porpoise, it is smooth and concave externally; but of a particular construction on the inner surface; for a tendinous process passes from it towards the malleus, converging as it proceeds from the membrane, and becoming thinner till its insertion into that bone. I could not discover whether it had any muscular fibres which could affect the action of the malleus. In the Piked Whale, the termination of the external opening, instead of being smooth and concave, is projecting, and returns back into the meatus for above an inch in length, is firm in texture, with thick coats, is hollow on its inside, and its mouth communicating with the tympanum; one side being fixed to the malleus, by a part similar to the tendinous process which goes from the inside of the membrana tympaui in the others."*

In the figure (*fig.*276), which represents the internal ear in the Balæna Mysticetus, the letters *c, d, e* indicate the extent of the membrana tympani, the letter *e* being placed on the part which forms a convex projection into the tympanic passage: *f* shows the triangular ligamentous process which attaches the handle of the malleus (*g*) to the membrana tympani. This connection between the membrane and the ossicles of the tympanum is denied by Sir Everard Home, who wrote a paper and published two plates in support of his opinion.† After quoting Mr. Hunter's description of the attachments of the membrana tympani in the Piked Whale, Sir Everard observes, "the fact is, that there is no connexion whatever between the membrana tympani and the malleus, as will be explained; but as that circumstance forms the great peculiarity in the organ of this species of Whale (*Balæna mysticetus*, L.)

* Hunter in Philos. Trans. 1787, p. 432.

† Philos. Trans. 1812, p. 88, pls. I. and II.

Fig. 276.



Internal ear of the Mysticete Whale.

I thought it right to quote what he had stated on this subject." So remarkable an anomaly as an absence of any communication between the membrana tympani and the ossicula auditus, would of itself, independently of our interest for the character of Hunter as an accurate observer, have induced us to spare no pains to test the conflicting statements with the facts themselves; fortunately in this instance the preparations figured by Sir Everard are preserved; we have carefully examined them, and find the following to be the true structure of the parts in question. The membrane marked *c* in Sir Everard Home's second figure is continuous at *d*, with *e* the convex projection of the membrana tympani; whereas the edge of the shadow is so strong in the figure as to make it appear as if *c* and *e* were separate membranes, as indeed Sir Everard describes them to be: they are, on the contrary, parts of the same membrana tympani, the attachment of which is extended inwards beyond the circumference of the termination of the bony meatus auditorius. The triangular ligament *f*, which is common to all the Cetacea, is attached not only to the plane portion of the ear-drum, but to the whole of one side of the convex portion which projects into the meatus, and is affected by every motion of that part. It is a thick opaque aponeurosis, and not, as it is represented in the plate, a semitransparent membrane passing clear over the convex part of the drum.

"A little way within the membrana tympani, are placed the small bones, which are three in number, as in the quadruped, malleus (*g*), incus (*h*), and stapes (*i*); but in the Bottle-nose Whale (Hyperoodon) there is a fourth, placed on the tendon of the stapedius muscle. These bones are as it were suspended between the bone of the tympanum, and that of the immediate organ.

"The malleus has two attachments, besides that with the incus; one close to the bone of the tympanum, which, in the Porpoise, is only by contact, but in others by a bony union; the other attachment is formed by the tendon, above described, being united to the inner surface of the membrana tympani. Its base articulates with the incus.

"The incus is attached by a small process to the tympanum, and is suspended between the malleus and stapes. The process by which it articulates with the stapes is bent towards that bone.

"The stapes stands on the vestibulum, by a broad oval base. In many of this tribe, the opening from side to side of the stapes is so small as hardly to give the idea of a stirrup.

"The muscles which move these bones are two in number, and tolerably strong. One arises from that projecting part of the tympanum which goes to form the Eustachian tube, and running backwards is inserted into a small depression on the anterior part of the malleus. The use of this muscle seems to be to tighten the membrana tympani; but in those which have the malleus anchylosed with the tympanum, we can hardly conjecture its use. The other (*o*) has its origin from the inner surface of the tympanum, and passing backwards is inserted into the stapes by a tendon, in which I found a bone in the large Bottle-nose. This muscle gives the stapes a lateral motion. What particular use in hearing may be produced by the action of these muscles I will not pretend to say; but we must suppose whatever motion is given to the bones must terminate in the movement of the stapes.

"The immediate organ of hearing is contained in a round bony process, and consists of the cochlea and semicircular canals, which somewhat resemble the quadruped; but besides the two spiral turns of the cochlea, there is a third, which makes a ridge within that continued from the foramen rotundum and follows the turns of the canal.

"The cochlea (*k*, *fig.* 276) is much larger when compared with the semicircular canals, than in the human species and quadruped."

Besides its greater relative size, the cochlea of the *Delphinidæ* differs from that of the human subject in the greater proportional extent, and especially the form and disposition of the scala vestibuli, which, instead of being one compartment of a single tube divided in the direction of its axis, is a complete conical tube. It also forms an oblique sigmoid curve before commencing its spiral turns, which are two and a half in number.

The semicircular canals have the same disposition as in Mammalia, but are relatively smaller.

Cuvier, in correcting the error into which Camper had fallen when he denied the existence of the semicircular canals in the Whale, appears to have overlooked the fact that they had previously been discovered in the Cetacea by Hunter. And it is simply because they do not possess any difference of note as compared with other Mammalia, (except in their relative volume to other parts of the labyrinth which Hunter is careful to point out,) that they are not described by him with the same miuuteness and detail as the cochlea and other parts of the organ. It may also be observed that the more extensive researches of Hunter preserved him from the error into which Cuvier has fallen of ascribing to the Cetacea a structure of the cochlea which is peculiar to a small part only of the order. The depression of the gyrations of the cochlea to nearly the same plane, and their limitation to one and a half in number, is certainly not applicable to the *Delphinidæ*, and it may be doubted how far it can be with accuracy asserted of the *Balænæ*.*

The canals which establish a communication between the labyrinth and the interior of the cranium, viz. the aqueductus vestibuli and aqueductus cochleæ, are very large in the *Delphinidæ*, especially the latter.]

Taste.—This sense probably exists in the Herbivorous Cetaceans, whose tongue, although but slightly moveable, has notwithstanding a complicated and delicate structure. But has this sense a special organ in the Spouting Cetaceans? Some doubts may be allowed to exist on this subject. The tongue of the Dolphin and that of the Porpoise have neither fossulate papillæ nor conical papillæ; they only present on their surface slight elevations, of which the middle appears to be perforated, and their edges are fringed, as if for multiplying the sensations of touch.

Touch.—The general organ of touch, the skin, has formed, in the Spouting Cetaceans, the subject of important researches, which have given a more extended knowledge of this organ in general than was before possessed.

According to the observations of MM. Breschet and Roussel de Vauzème, there may be distinguished in the skin of the Cetaceans, as in that of other Mammals, six principal constituents which either penetrate or are superimposed on one another, but which are severally destined to fulfil a special function.

1. The derm or *corium* (*le derme*), a dense fibrous cellular texture, which contains and protects all the other parts of the skin. In the Whale it is constantly white and opake, and its peripheral surface presents a series of papillæ, the intervals of which are occupied by the epidermis, which forms for each a sheath.

2. The papillary bodies (*les corps papillaires*) consist of papillæ covered by the derm. They have a nacrous lustre, and are several lines in length in the Whale, but are much shorter in the common Dolphin and Porpesse. These papillæ are composed of fibres penetrated by vessels; they originate from the subcutaneous nervous plexus and return back again to the same; the derm serves merely as a sheath to the papillæ, the extremities of which exercise the sense of touch.

3. The sudorific apparatus (*l'appareil sudorifique*) consists of soft, elastic, spiral canals, which extend through the entire thickness of

* See Ossem. Foss. vol. v. pt. i. p. 300, and Leçons d'Anat. Comparée, vol. ii. p. 467.

the derm, and open in the intervals of the papillæ by an orifice generally closed by a small epidermic valve.

4. The inhalent apparatus *(l'appareil d'inhalation)* is formed by extremely delicate canals, which are smooth, straight, silvery, branched, and very easily ruptured: they originate in a plexus extended in the dermis beneath the sudorific canals, anastomose together, and are provided with partitions. The lymphatic vessels have no connection with these canals, which communicate directly with the arteries and veins. They are absorbing canals.

5. The mucous apparatus *(l'appareil blennogène)*. This is composed of secerning glands and excretory ducts, which open between the papillæ like the orifices of the preceding canals. It is wholly contained in the derm, and produces a mucous material, which by desiccation *(en se dessechant)* becomes the cuticle. In the Whales this cuticle acquires an extreme thickness: it is much thinner in the Dolphins.

6. The colorific apparatus *(l'appareil chromatogène)* is likewise composed of secerning glands and excretory ducts; it is situated in the first superior (peripheral) layers of the corium on the right and left sides of the outlet of the excretory ducts of the preceding apparatus, and it pours out the coloured product at the same point where the mucous matter is excreted, where it stains it.

[It may be questioned how far this explanation satisfactorily accounts for the formation of cuticle in animals living habitually under water. The whole account is to be received with reserve, and requires to be confirmed by further observations, especially as regards the reflexion of the nervous fibrils and the sudorific and inhalent apparatuses.]

We do not stop to examine how far this analysis serves to explain the different phenomena which the external teguments of the Mammalia present. But admitting it as it is presented to us, it results that the sensations of touch must be lively and delicate in the Cetacea: the great development of their papillary apparatus leads to this conclusion. Nevertheless, the most generally received opinion is that the common Dolphin, notwithstanding the delicacy of its epidermis, has hut little tactile sensibility. But is this opinion devoid of foundation? or is it explicable on the ground of the deposition of fat, which penetrates every part of the skin, and is accumulated in a dense layer beneath it, so as to enfeeble the sensibility of the surface, according to the common belief. This is the opinion to which we have arrived. With respect to the Balænidæ no difficulty exists on account of the thickness and horny texture of the epidermis.

[According to Hunter's views the reticular network containing the blubber, which he describes as fine in the Porpoise, Spermaceti, and large Whale-bone Whale *(Balæna)*, and coarse in the Grampus and small Whale-bone Whale *(Balænoptera)*, forms part of the skin; for he observes that "the cutis seems to be the termination of the cellular membrane of the body more closely united, having smaller interstices and becoming more compact," and that the distinction between the skin and cellular membrane is much less obvious in fat than in lean animals; "for the cells of both membrane and skin being loaded with fat, the whole has more the appearance of one uniform substance. This uniformity of the adipose membrane and skin is most observable in the Whale, Seal, Hog, and the Human Species."*]

In the *Balænopteræ* the integument covering the ventral surface of the neck, thorax, and anterior part of the abdomen, is disposed in longitudinal folds, about five-eighths of an inch in breadth in the contracted state. The skin is very soft in the insterstices of the folds, and covered there with a thinner cuticle: it possesses great elasticity over the whole of the plicated surface. A panniculus carnosus adheres closely to this part of the skin, but is separated by a loose cellular membrane from the deep-seated muscles; in which space the blubber is in smaller quantity than on the dorsal and lateral parts of the body.

Besides the adipose substance which is accumulated beneath the integument, another secretion of a peculiar kind, called Spermaceti, which is analogous in many of its properties to the adeps, is met with in certain species of Cetacea, but more particularly in the genera *Catodon* and *Physeter*, which are hence termed Spermaceti Whales. Of this substance Mr. Hunter gives the following account from a dissection of a recent specimen of one of these Whales.

["What is called spermaceti is found every where in the body in small quantity, mixed with the common fat of the animal, bearing a very small proportion to the other fat. In the head it is the reverse, for there the quantity of spermaceti is large when compared to that of the oil, although they are mixed, as in the other parts of the body.

"As the spermaceti is found in the largest quantity in the head, and in what would appear on a slight view to be the cavity of the skull, from a peculiarity in the shape of that bone, it has been imagined by some to be the brain.

"These two kinds of fat in the head are contained in cells, or cellular membrane, in the same manner as the fat in other animals; but besides the common cells there are larger ones, or ligamentous partitions going across, the better to support the vast load of oil, of which the bulk of the head is principally made up.

"There are two places in the head where this oil lies; these are situated along its upper and lower part: between them pass the nostrils, and a vast number of tendons going to the nose and different parts of the head.

"The purest spermaceti is contained in the smallest and least ligamentous cells: it lies above the nostril, all along the upper part of

* Ibid. p. 395.

the head, immediately under the skin, and common adipose membrane. These cells resemble those which contain the common fat in the other parts of the body nearest the skin. That which lies above the roof of the mouth, or between it and the nostril, is more intermixed with a ligamentous cellular membrane, and lies in chambers whose partitions are perpendicular. These chambers are smaller the nearer to the nose, becoming larger and larger towards the back part of the head, where the spermaceti is more pure.

"This spermaceti, when extracted cold, has a good deal the appearance of the internal structure of a water melon, and is found in rather solid lumps.

"About the nose, or anterior part of the nostril, I discovered a great many vessels, having the appearance of a plexus of veins, some as large as a finger. On examining them, I found they were loaded with the spermaceti and oil; and that some had corresponding arteries. They were most probably lymphatics; therefore I should suppose, that their contents had been absorbed from the cells of the head. We may the more readily suppose this, from finding many of the cells, or chambers, almost empty; and as we may reasonably believe that this animal had been some time out of the seas in which it could procure proper food, it had perhaps lived on the superabundance of oil.

"The solid masses are what are brought home in casks for spermaceti.

"I found, by boiling this substance, that I could easily extract the spermaceti and oil which floated on the top from the cellular membrane. When I skimmed off the oily part, and let it stand to cool, I found that the spermaceti crystallised, and the whole became solid; and by laying this cake upon any spongy substance, as chalk, or on a hollow body, the oil drained all off, leaving the spermacéti pure and white. These crystals were only attached to each other by edges, forming a spongy mass; and by melting this pure spermaceti, and allowing it to crystallise, it was reduced in appearance to half its bulk, the crystals being smaller and more blended, consequently less distinct.

"The spermaceti mixes readily with other oils, while it is in a fluid state, but separates or crystallises whenever it is cooled to a certain degree; like two different salts being dissolved in water, one of which will crystallise with a less degree of evaporation than the other; or, if the water is warm, and fully saturated, one of the salts will crystallise sooner than the other, while the solution is cooling. I wanted to see whether spermaceti mixed equally well with the expressed oils of vegetables when warm, and likewise separated and crystallised when cold, and on trial there seemed to be no difference. When very much diluted with the oil, it is dissolved or melted by a much smaller degree of heat than when alone; and this is the reason, perhaps, that it is in a fluid state in the living body.

"If the quantity of spermaceti is small in proportion to the other oil, it is, perhaps, nearly in that proportion longer in crystallising; and when it does crystallise, the crystals are much smaller than those that are formed where the proportion of spermaceti is greater. From the slowness with which the spermaceti crystallises when much diluted with its oil, from a considerable quantity being to be obtained in that way, and from its continuing for years to crystallise, one would be induced to think, that perhaps the oil itself is converted into spermaceti.

"It is most likely, that if we could discover the exact form of the different crystals of oils, we should thence be able to ascertain both the different sorts of vegetable oils, much better than by any other means; in the same manner as we know salts by the forms into which they shoot."*]

Organs of Generation.—The organs concerned in the reproduction of the species do not exhibit the same type of conformation in the Phytophagous as in the Zoophagous species. In the former the mammæ are pectoral, in the latter inguinal or rather pudendal, since they are situated on each side of the vulva: in both orders their number never exceeds two. The vulva, which resembles in its form that of the Ruminants, presents nothing peculiar in its structure.

The penis is attached to the rudimental bones of the pelvis; in the Phytophaga the glans is complicated, but in the Zoophaga it is of a simple elongated fusiform shape: in all the species it is provided with a prepuce.

[According to Hunter, the parts of generation in both sexes of this order of animals come nearer in form to those of the Ruminants than of any others; and this similarity is, perhaps, more remarkable in the female than in the male; for their situation in the male must vary on account of the modification of the external form of the body.

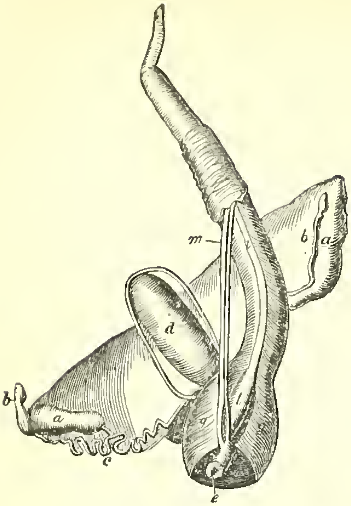
The testicles (*a, a, figs.* 277, 278) retain the situation in which they were formed, as in those quadrupeds in which they never come down into the scrotum. They are situated near the lower part of the abdomen, one on each side, upon the two great depressors of the tail. At this part of the abdomen, the testicles come in contact with the abdominal muscles anteriorly.

The vasa deferentia (*c, c*) pass directly from the epididymis (*b, b*) behind the bladder (*d, d*) or between it and the rectum (*e*) into the urethra (*f*); and there are no bags similar to those called vesiculæ seminales in certain other animals.

The structure of the penis is nearly the same in them all, and formed much upon the same principle as in the quadruped. It is made up of two crura (*g, g*), uniting into one corpus cavernosum, and the corpus spongiosum seems first to enter the corpus cavernosum. In the Porpoise, at least, the urethra is found nearly in the centre of the corpus cavernosum; but towards the glans seems to separate or

* Philos. Trans. 1787, p. 390.

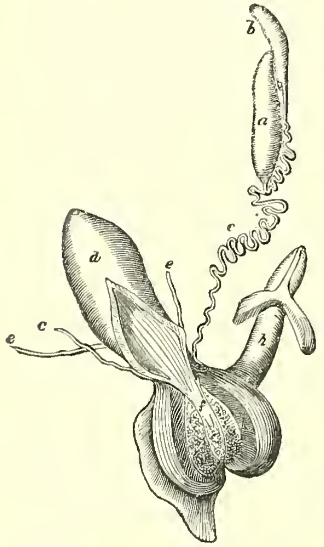
Fig. 277.



Male Organs of a Porpesse.

emerge from it, and becoming a distinct spongy body, runs along its under surface, as in quadrupeds (*h*). The corpus cavernosum in some is broader from the upper part to the lower than from side to side; but in the Porpoise (*fig*. 277) it has the appearance of being round, becoming smaller forwards, so as to terminate almost in a point some distance from the end of the penis. The *glans* does not spread out as in many quadrupeds, but seems to be merely a plexus of veins covering the anterior end of the penis, yet is extended a

Fig. 278.



Male Organs of a Dolphin.

good way further on, and is in some not more than one vein deep.

The crura penis are attached to two bones, which are nearly in the same situation and in the same part of the pelvis as those to which the penis is attached in quadrupeds; but these bones are only for the insertion of the crura, and not for the support of any other part, like the pelvis in those animals which have posterior extremities, neither do they meet at the fore part, or join the vertebræ of the back.

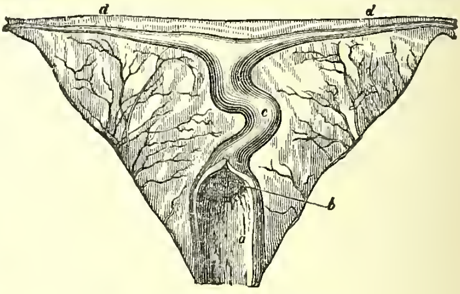
The *erectores penis* (*g*, *g*, *fig*. 277) are very strong muscles, having an origin and insertion similar to those of the human subject.

The prostatic portion of the urethra (*f*, *fig*. 278) is surrounded by a muscle of prodigious thickness (*k*, *k*), destined to compress and forcibly expel the eontents of that part of the canal.

The acceleratores muscles (*l*) are likewise very strong; and there is a pair of strong and long muscles (*m*, *fig*. 277) arising from the anus, and passing forwards to the bulb of the penis, that run along the under surfaee of the urethra, and are at last lost or inserted in the corpus spongiosum. These muscles draw the penis into the prepuce, and throw that part of the penis that is behind its insertion into a serpentine form. These muscles are common to most animals that draw back the penis into what is called the sheath, and may be called the retractores penis.

The female organs in the Phytophagous Cetaeea have been described by Steller as they exist in the *Rytina*, and by Home in the *Dugong;* the latter author has given a figure of the uterus with part of the vagina: (see *fig*. 279.) In both species the vagina (*a*) is characterized by the longitudinal rugæ of its inner surface. The body of the uterus (*c*) commences by a single os tincæ (*b*) in the

Fig. 279.



Uterus of the Dugong.

Dugong, and gives off the cornua uteri (*d*, *d*) at right angles.* The structure of the Fallopian tubes and ovaries is not described. Steller states that in the Rytina they resemble those of the Mare. The vulva he describes as of a triangular form, with the clitoris, which is of a gristly texture, and an inch and a half long,

* See Home, in Phil. Trans. 1820, p. 321.

situated at the anterior broad part of the opening, which is eight inches anterior to the anus.

In all the females of the zoophagous tribe of Cetacea which Hunter examined, the parts of generation were very uniformly the same; consisting of the external opening, the vagina, the body and two horns of the uterus, Fallopian tubes, fimbriæ, and ovaria.

"The external opening is a longitudinal slit, or oblong opening, whose edges meet in two opposite points, and the sides are rounded off, so as to form a kind of sulcus. The skin and parts on each side of this sulcus are of a looser texture than on the common surface of the animal, not being loaded with oil, and allowing of such motion of one part on another as admits of dilatation and contraction. The vagina passes upwards and backwards towards the loins, so that its direction is diagonal respecting the cavity of the abdomen, and then divides into the two horns, one on each side of the loins; these afterwards terminating in the Fallopian tubes, to which the ovaria are attached. From each ovarium there is a small fold of the peritoneum, which passes up towards the kidney of the same side, as in most quadrupeds.

"The inside of the vagina is smooth for about one-half of its length, and then begins to form something similar to valves projecting towards the mouth of the vagina, each like an os tincæ: these are about six, seven, eight, or nine in number. Where they begin to be formed, they hardly go quite round, but the last are complete circles. At this part, too, the vagina becomes smaller, and gradually decreases in width to its termination. From the last projecting part, the passage is continued up to the opening of the two horns, and the inner surface of this last part is thrown into longitudinal rugæ, which are continued into the horns. Whether this last part is to be reckoned common uterus or vagina, and that the last valvular part is to be considered as os tincæ, I do not know; but from its having the longitudinal rugæ, I am inclined to think it is uterus, this structure appearing to be intended for distinction.

"The horns are an equal division of this part; they make a gentle turn outwards, and are of considerable length. Their inner surface is thrown into longitudinal rugæ, without any small protuberances for the cotyledons to form upon, as in those of ruminating animals; and where they terminate the Fallopian tubes begin.

"In the Bottle-nose Whale (*Delphinus Tursio*), where the Fallopian tubes opened into the horns of the uterus, they were surrounded by pendulous bodies hanging loose in the horns.

"The Fallopian tubes, at their termination in the uterus, are remarkably small for some inches, and then begin to dilate rather suddenly; and the nearer to the mouth the more this dilatation increases, like the mouth of a French horn, the termination of which is five or six inches in diameter. They are very full of longitudinal rugæ through their whole length.

"The ovaria are oblong bodies, about five inches in length; one end attached to the mouth of the Fallopian tube, and the other near to the horn of the uterus. They are irregular on their external surface, resembling a capsula renalis or pancreas. They have no capsula but what is formed by the long Fallopian tube.

"How the male and female copulate I do not know; but it is alleged that their position in the water is erect at that time, which I can readily suppose may be true; for otherwise, if the connexion is long, it would interfere with the act of respiration, as in any other position the upper surface of the heads of both could not be at the surface of the water at the same time. However, as in the parts of generation they most resemble those of the ruminating kind, it is possible they may likewise resemble them in the duration of the act of copulation, for I believe all the ruminants are quick in this act.

"Of their uterine gestation I as yet know nothing, but it is very probable that they have only a single one at a time, there being only two nipples. This seemed to be the case with the Bottle-nose Whale, caught near Berkeley, which had been seen for some days with one young one following it, and they were both caught together.

"The glands for the secretion of milk are two, one on each side of the middle line of the belly at its lower part. The posterior ends, from which go out the nipples, are on each side of the opening of the vagina in small sulci. They are flat bodies lying between the external layer of fat and abdominal muscles, and are of considerable length, but only one-fourth of that in breadth. They are thin, that they may not vary the external shape of the animal, and have a principal duct, running in the middle through the whole length of the gland, and collecting the smaller lateral ducts, which are made up of those still smaller. Some of these lateral branches enter the common trunk in the direction of the milk's passage, others in the contrary direction, especially those nearest to the termination of the trunk in the nipple. The trunk is large, and appears to serve as a reservoir for the milk,* and terminates externally in a projection, which is the nipple. The lateral portions of the sulcus which incloses the nipple are composed of parts looser in texture than the common adipose membrane, which is probably to admit of the elongation or projection of the nipple. On the outside of this there is another small fissure, which I imagine is likewise intended to give greater facility to the movements of all these parts. The milk is probably very rich; for in that caught near Berkeley with its young one, the milk, which was tasted by Mr. Jenner, and Mr. Ludlow, surgeon, at Sodbury, was rich like cow's milk to which cream had been added.

"The mode in which these animals must

* The description of this structure has lately been reproduced as a new discovery by Geoffroy St. Hilaire.

suck would appear to be very inconvenient for respiration, as either the mother or young one will be prevented from breathing at the time, their nostrils being in opposite directions, therefore the nose of one must be under water, and the time of sucking can only be between each respiration. The act of sucking must likewise be different from that of land animals; as in them it is performed by the lungs drawing the air from the mouth backwards into themselves, which the fluid follows, by being forced into the mouth from the pressure of the external air on its surface; but in this tribe, the lungs having no connexion with the mouth, sucking must be performed by some action of the mouth itself, and by its having the power of expansion."

Much stress has recently been laid on the supposed existence which the muscles surrounding the mammary gland afford in the act of suckling by compressing the gland and ejaculating the milk accumulated in the dilated receptacle above described; but when we consider how great the pressure of the surrounding water must be upon the extended surface of the mammary gland, we may readily conceive that when the nipple is grasped by the mouth of the young, and the pressure removed from it by the retraction of the tongue, the milk will be expelled in a copious stream by means of the surrounding pressure alone, independently of muscular aid.

The intimate structure of the mammary gland in the Zoophagous Cetacea is essentially the same as in the Ornithorhynchus, being composed of an innumerable quantity of small elongated cœcal tubes; these are, however, shorter than in the Ornithorhynchus, and their glandular parietes are firmer; they are well shown in the figure of the mammary gland of a young Piked Whale, *(Balænoptera Rostrata,)* given by Müller in his pl. xvii. *fig.* 2, and according to that author present, after the Ornithorhynchus, the simplest structure of the mammary gland in the entire mammiferous series of animals.]

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(The preceding article has been derived from the work last named in the Bibliography, with the addition of the extracts from Mr. Hunter's papers and the other passages included between brackets.)

(F. Cuvier.)

CHEIROPTERA, (from χειρ, *manus,* πτερον, *ala,)* Bats, Fr. *Chauvesouris,* Germ. *Fledermäuser,* an order of mammiferous quadrupeds, consisting of such as have a generally insectivorous type of dentition, with the extremities connected together by an aliform expansion of the integuments, for the purpose of flight. The question whether this group, as well as that of the CARNIVORA and that of the INSECTIVORA, ought to be considered as forming a single order according to the method of Cuvier, has been already sufficiently adverted to under the head CARNIVORA; and it needs only to be now observed that if there were sufficient ground for giving to the last-mentioned group a separate consideration, either on account of expediency and convenience, or on that of natural arrangement, the same reasons hold good, in the present case, in an equal, if not a superior degree.

The distinctions by which the present order is separated from all others are so marked, and the general similarity in the organization of its component groups is so striking, as greatly to facilitate and shorten the necessary detail of the organization.

There appears to be a great and obvious objection to the usual location of the remarkable genus *Galeopithecus* amongst the *Cheiroptera;* there are so many important parts of its organization in which it clearly resembles the more insectivorous forms of the *Quadrumana*, not only in the peculiarities of its osteology, but in many other not less essential points, that I have preferred following the change suggested by Blainville, and subsequently adopted by Temminck, to the arrangement of Cuvier and of most other zoologists. It may undoubtedly be considered as an osculent form, leading from the Quadrumanous order, by the Makis, &c. to the present group; but it cannot but be acknowledged by any one who has attentively marked its anatomical structure, that the affinity of this genus to the Quadrumana is more intimate than that by which it approaches the Bats; though perhaps it would be going too far to say, with Temminck, that it bears the same relation to the *Quadrumana* as *Petaurista* to the *Marsupiata*, or *Pteromys* to the *Rodentia*. The latter genera are not even on the confines of their respective orders, nor do they offer any important aberration from the typical structure; but in the present case there are several characters which indicate an interesting approach towards the order from which it has very properly been removed.

Omitting, then, the genus *Galeopithecus*, the *Cheiroptera* form, without perhaps a single exception, the most distinctly circumscribed and natural group to be found in the whole class of the *Mammifera*. The characters by which the order thus restricted is distinguished are as follow:—

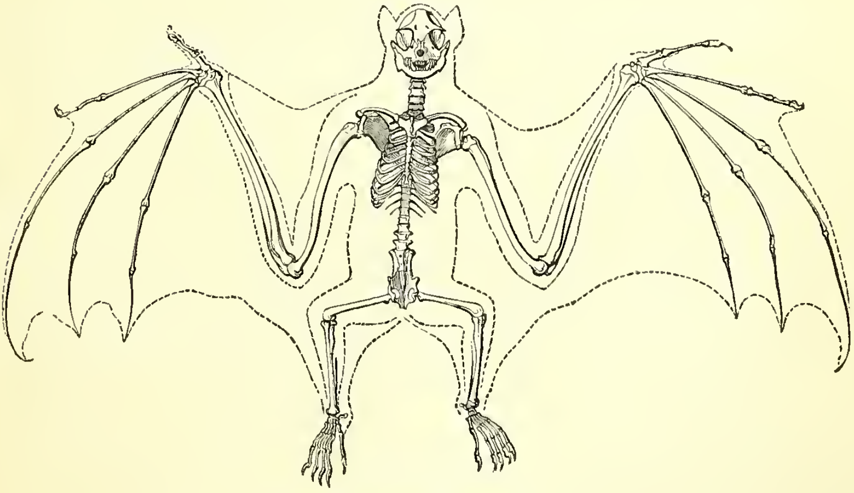
General form disposed for flight; an expansion of the integument stretched between the four members, and the fingers of the anterior extremities, which are greatly elongated for that purpose; the flying membrane naked, or nearly so, on both sides. *Mammæ* pectoral, clavicles very robust; fore-arm incapable of rotation, in consequence of the union of the bones of which it is composed.

The *Cheiroptera* consist of two distinct groups; of which the first, containing the genera *Pteropus* and *Cephalotes*, is frugivorous, and distinguished by the molar teeth being obliquely truncated and longitudinally grooved, and by the existence of a third phalanx, which is in general provided with a little nail on the index or second finger, and by the absence or rudimentary condition of the tail. The second, consisting of the insectivorous bats, (*Chauve-souris vraies*, Cuv. *Vespertilionidæ*, Gray,) have the molares furnished with acute points, similar to those of other insectivora.

Osteology.—The evident object in the general structure of the skeleton of the *Cheiroptera* (*fig.* 280) is to combine as great a degree of lightness as possible with great extension of the anterior extremities, for the purposes of flight. The general form of the head differs in the two grand divisions of the Cheiroptera by the different lengths of the cranium; and this diversity is exactly conformable with that which exists in other families. The frugivorous group (*fig.* 281, 282, 283) has a much more elongated form than the insectivorous (*fig.* 284, 285, 286), arising principally, though not wholly, from the form of the maxillary and intermaxillary bones.

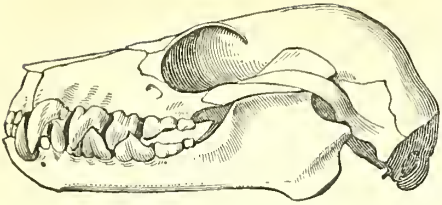
The cranium is generally rounded, and rather broad. The posterior aspect more or less convex in different groups; in some overhanging

Fig. 280.



Skeleton of Pteropus.

Fig. 281.



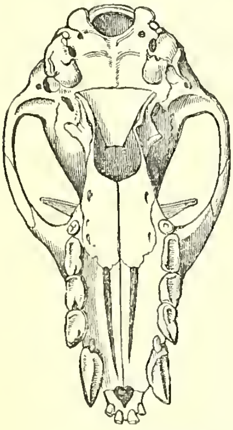
the occipital foramen, in others not so. The occipital crest is triangular, stronger in the insectivorous than in the frugivorous form. In many there is also a longitudinal crest. The face is broad. The orbits are not complete in either group, and the *temporal fossa* is large, but the *zygoma* in many very slender; in some it is horizontal, in others slightly convex above. The nasal opening is very considerable; and in many whole genera, as in *Rhinolophus*, in *Plecotus*, and several others, in consequence of the intermaxillary bones not meeting each other, it is not closed at the lower part. In the genus *Pteropus*, and some others, as is seen in *fig.* 282, 283, though the intermaxillary bones meet in front, yet, as the arch is very small and narrow from before backwards, the palatine foramina unite and form a single large opening.

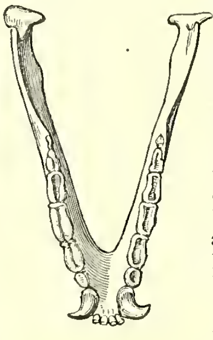
From the extreme thinness of the cranial bones, the internal surface corresponds exactly with the external, and there is no vestige of a bony *tentorium*, which is so strong in many of the *Carnivora*.

The frontal bone in the genus *Pteropus* presents a prominent orbitar process; it resembles that of Man, and of the *Quadrumana*, in the circumstance of the two portions becoming early united. *The parietals*, also, unlike those of the examples just named, form but a single bone.

The temporal bone has a very extensive development of its acoustic portion; a character which is of the utmost importance to their peculiar habits, as the organ of hearing requires to be extensive in those animals which prey by night, and especially in such as feed upon insects and pursue them on the wing.

Fig. 282. *Fig.* 283.





Cranium of Pteropus.

The occipital bone is remarkable from the narrowness of its body, the transverse direction of the condyles, the short, thin, and convex form of its squamous portion, and particularly from the unparalleled proportionate size of the occipital foramen, which is nearly vertical and rounded.

Fig. 284. *Fig.* 285.

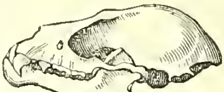
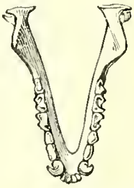


Fig. 286.



Cranium of Phyllostoma.

The jugal bone is small in most of the bats and very strait.

The superior maxillary bone is considerably elongated in this order, particularly in the frugivorous genera. The difference in this respect which exists betwcen the frugivorous and insectivorous forms is shewn in the *cranium* of a *Pteropus* belonging to the former (*fig.* 281, 282, 283), and a *Phyllostoma* to the latter group (*fig.* 284, 285, 286). In the former case, the portion occupied by the teeth fully equals in length the portion of the cranium posterior to it; in the latter it is little more than as two to three. The number of teeth contained in this bone varies considerably. There is, however, always a single canine tooth on each side, which is tolerably robust and sharp. The molares of the insectivorous Bats are always shorter than those of the frugivorous, and are furnished with sharp points, the latter being truncated and longitudinally grooved. They vary in number from $\frac{3}{3}$ to $\frac{5}{6}$, or $\frac{6}{5}$.

The intermaxillary bones are always very small and short; they contain small *incisores*, varying in number according to the genera, from two to four in the upper, and in the lower jaw from two to six, there being always either the same number in the two jaws, or two more in the lower than in the upper; thus there is always one of the following formulæ—$\frac{2}{2}$ $\frac{2}{4}$ $\frac{4}{4}$ $\frac{4}{6}$. The articulation of the lower jaw is transverse. The ascending ramus, with its coronoid process, is large and strong, rising very high above the level of the condyle.

The vertebral column.—The cervical vertebræ are in general very little raised, but they are developed laterally, so as to present the broadest portion of the whole vertebral column, and the spinous processes are wanting from the second to the sixth vertebra. The *Atlas* is large, the *dentata* small, and its spinous process inconsiderable. *The dorsal vertebræ* are of a very simple construction; they are almost without spinous processes, which are replaced by a small tubercle: the bodies are, however, much compressed at the sides, so as to form a sort of crest. The vertebral canal is very large in this region. These vertebræ are twelve in number in both forms, excepting in some species of the single genus *Vespertilio*, in which they are only eleven. *The lumbar vertebræ* retain the peculiar characters which have been mentioned as belonging to the dorsal. They are elongated, and still almost devoid of spinous processes; they are also compressed into a sort of continuous crest. The number of these vertebræ is four in *Pteropus*, five in *Phyllostoma* and *Vespertilio*, six in *Rhinolophus*, seven in *Noctula*.

The sacrum is particularly elongated and narrow, and the spinous processes large. The number of *sacral vertebræ* varies much. In *Pteropus* (*fig*. 280) there is but one. In the other genera they are either three or four. In *Pteropus* the sacrum is united at its extremity to the tuberosities of the *ischium*.

The coccygeal vertebræ are slender, elongated, and nearly cylindrical; the tail being always included within the flying membrane, the only use of this part is to assist in supporting the interfemoral portion of that membrane. In most the tail reaches to its margin, in some much beyond, in others only half-way, and in *Pteropus* (*fig*. 280) there is not the least appearance of a tail, there is not even a rudiment of a coccygeal bone. The number of these vertebræ is but six in *Noctula*, twelve in *Vespertilio* and some others.

The number of vertebræ in the whole column is said to be less in *Pteropus* than in any other mammiferous animal, being only twenty-four, namely, 7C+12D+4L+1S=24.

The ribs are the same in number as the *dorsal vertebræ*. The first rib is very short and remarkably broad, and its cartilage, which is ossified, is still more so. The rest of the ribs follow the usual variations of form.

The Bats are remarkable for the extraordinary proportional length of their ribs, in which they probably exceed all other *Mammifera*.

The sternum is altogether greatly developed in the whole of this order. Its length is considerable, and this circumstance, with the length of the ribs, tends to afford a great protection to the thorax in the violent movements required by the act of flight. But the most remarkable peculiarity exhibited in the structure of this part, is the extraordinary lateral development of the anterior portion of this bone, termed the *manubrium*. This expansion is conspicuous in all the Bats, and appears to be intended to afford the strongest possible attachment for the clavicles, which are also very much developed. In the genus *Rhinolophus* (the Horse-shoe Bat), this expansion seems to have reached its maximum of development. Its breadth is four times as great as its length, and yet it is nearly as long as the whole remaining portion of the *sternum*. The inferior surface of the *manubrium* is also furnished with a crest, which is continued, though much smaller, on the next piece of the *sternum*; it varies in size in the different genera. The remaining bones composing the sternum are of nearly equal size.

The anterior extremity is the part of the skeleton which in the true *Cheiroptera* offers the most remarkable deviation from the normal form, especially in the *metacarpal* and *phalangeal* bones.

The clavicle, from the extensive motion of the anterior extremities, requires to be much elongated in these animals; some of which in fact exhibit proportionally a greater development of this bone than is to be found in any other order. It is always arched above and intimately articulated both to the *scapula* and to the *sternum*, and in some species is half as long as the greatly elongated *humeras*. As far as I have had an opportunity of observing, the clavicle, as well as the other portions of this extremity, is more developed in the insectivorous than in the frugivorous Bats, for the very obvious reason that the former require more extensive powers of flight in the pursuit of their swift and active prey, than the latter in merely flying from place to place, in search of their stationary food.

The scapula is also developed to the greatest extent, and particularly in the insectivorous Bats. It is greatly elongated towards the base and posterior angle, which in some species reaches nearly to the last rib. The inner surface is very concave, and the *fossæ* above and below the spine are deep, for the attachment of the powerful muscles which are inserted to it.

The humeras is very long, slender, and cylindrical, as may be observed in the skeleton of *Pteropus* in *fig*. 280. The head of the bone is round and large. The whole anterior part of the inferior articulation or elbow-joint corresponds to the head of the *radius*.

The fore-arm consists, as in the other *mammifera*, of the *radius* and the *ulna*. The latter bone is, however, in all the *Cheiroptera* exceedingly small, and in some merely rudimentary. In several species of *Vespertilio*, for instance, it forms nothing more than a flat process, only partially separated from the *radius*. In the example shewn at *fig*. 280 it is more considerable; but even here it presents nothing more than a small styliform bone, united to the radius at the head, and diminishing to a thin point, towards the carpal extremity; the olecranon too is wholly wanting.

The radius, like the other bones of the anterior extremity, is remarkably elongated, and rather robust. The absence of rotation in the forearm of these animals forms an admirable adaptation to their habits. Not only would the pronation and supination of the hand be wholly useless to them, but at every impulse of their flight such a motion would deprive the whole limb of its resistanee to the air, or it would require the constant exertion of such a degree of antagonizing muscular force to prevent it, as would be incompatible with the essential structure of these organs of flight.

The carpus is of a very peculiar structure. The first series of bones consists but of two; one very large, on which the *radius* rests, and which is probably formed of the three outer bones, the scaphoid, the semilunar, and the cuneiform bones; the other extremely small, which is undoubtedly the pisiform, on the ulnar side.

The second series consists of the four bones of which it is usually constituted.

The metacarpal bones and phalanges of all the fingers excepting the thumb are extremely elongated. They extend outwards and downwards in a slightly curved direction to the margin of the flying membrane, the second finger being the shortest and extending to the upper angle of the outer margin, the third, fourth, and fifth to the inferior margin of the membrane. There is a slight enlargement at the articulation of the metacarpal bones with the phalanges; but otherwise these bones are extremely slender and cylindrical. The thumb is of no extraordinary length, and the ultimate phalanx is hooked and sustains a nail, by which the animal is enabled to climb on any rough perpendicular surface, or to suspend itself from some projecting part.

The pelvis is remarkably strait, rather elongated, somewhat wider inferiorly. The *ilia* are narrow and elongated; the *ischia* in several species, instead of receding from each other, approach so that their tuberosities touch each other, and in some instances come in contact with the coccygeal bones. In some species of *Pteropus*, the anterior portion of the ossa pubis, instead of meeting at the median line, recede more or less from each other, and the space is filled by ligament. In some species there is a sexual difference in this respect; the two pubic bones being in contact in the male and separated in the female.

The *sacrum* and the *ilia* are connected by absolute bony union at an early period. *The femur* is of moderate length, slender and cylindrical. It is turned outwards and upwards, so that the side which is usually anterior is directed nearly backwards. *The tibia* offers no peculiarity which requires particular notice. *The fibula* is exceedingly small, slender, pointed towards its femoral extremity, and has this singular peculiarity, that it does not rise to the head of the tibia. In other cases where this bone is defective, it is at its inferior extremity, but in the present case it is the superior portion which is wanting. As the *femora* are directed outwards, the leg-bones are in some measure turned round, so that the *fibulæ* are at the inner side of the *tibiæ* and a little behind them.

The foot of the *Cheiroptera* does not exhibit the same deviation from the normal structure which we have seen in the hand. On the contrary, it is not extraordinarily developed, and the different parts of which it is composed are in the usual relative proportions.

The tarsus is composed of the usual bones. There is a peculiarity in the heel, however, which is worthy of notice. There is a long, slender, pointed, bony process from the posterior part of the foot which is inclosed within the folds of the margin of the interfemoral membrane, and extends about half-way to the tail. Whether this process is a portion of the *os calcis*, according to Cuvier, or a distinct bone according to Daubenton, it is perhaps difficult to decide; but the opinion of Meckel is probably the correct one, that it is nothing more than a development of the tuberosity of that bone, remaining disunited from its body.

The metatarsal bones are rather short, slender, and of nearly equal length.

The phalanges of the five toes are nearly equal, the inner toe reaching almost to the same length as the others, in consequence of the greater elongation of its first *phalanx*. The ultimate *phalanges* are furnished with hooked nails, by which these animals constantly suspend themselves when at rest with the head downwards.

The whole of this structure is so perfectly adapted to the peculiar habits of the animals, as to require no comment. The great development of the ribs, sternum, and scapula, for the attachment of strong muscles of flight, the length and strength of the clavicle, the extension of all the bones of the anterior extremities, all admirably tend to fulfil their obvious end. The existence of a tail for the support and extension of the interfemoral membrane, which is found in the insectivorous Bats, compared with its absence or comparative inefficiency in many of the frugivorous, also points out an interesting relation to the different habits of the two groups, the former structure being calculated to afford a powerful and effective rudder in guiding their rapid and varying evolutions in the pursuit of their insect food.

The general *nervous system* in the Cheiroptera does not exhibit any very remarkable peculiarity, but some of the organs of sense require a particular notice.

Organs of the Senses.—The organ of vision is principally remarkable for its diminutive size. The eye in many of the insectivorous group, in which the external ear is very largely developed, is placed within the margin of the auricle and almost concealed by hair. In the frugivorous group, on the other hand, it is of the usual proportional size. *The organ of hearing*, on the contrary, though in the latter forms not more developed than in most other quadrupeds, in the former seems to take the place of the diminutive organ of vision, being greatly extended both in its external and internal organization. The external ear in *Pteropus* is of the usual form and dimensions, and the eminences are not in any respect extraordinary: but in most of the insectivorous Bats the conch of the ear is enormously large; in many species being considerably larger and longer than the head, and in the common long-eared Bat of this country, *Plecotus auritas*, it is nearly as long as the body. The tragus is proportionally larger than in any other animals;

in most species it is more or less lanceolate in its form; in *Vespertilio spasma* it is forked, and in the great Bat of Britain, *Vespertilio noctula*, it is short, blunted, with a rounded head, thickish, and I have observed it beset with numerous minute glands, which do not occur in those species having the thin lanceolate form of this part. Its use is probably to prevent the rush of air into the open ear during flight; and where it does not exist, as in the Horse-shoe Bats (*Rhinolophus*), its place is supplied by a large rounded lobe which is capable of still more effectually closing the external meatus.

In the *internal ear* there is an equal diversity of structure in the two groups in question. The *cochlea* is particularly developed in the insectivorous group; being much larger than the semicircular canals; the circumference of that of *Rhinolophus* is no less than four times the circumference of the canals, and its cavity exhibits ten times the diameter of one of them. In *Pteropus* this disproportion is very much less. The *meatus* is short and, as well as the tympanic cavity, extremely large and open.

But it is in the sense of *touch* probably that the most extraordinary and interesting peculiarities are to be observed. Spallanzani having observed the power which these animals possess of flying with perfect accuracy in the dark, and of avoiding every obstacle that presents itself with the same unerring certainty as in the light, instituted a series of experiments, the results of which proved that bats when deprived of sight by the extirpation of the eyes, and, as far as possible, of hearing and smell by the obliteration of the external passages of those senses, were still capable of directing their flight with the same security and accuracy as before, directing their course through passages only just large enough to admit them without coming into contact with the sides, and even avoiding numerous small threads which were stretched across the room in various directions, the wings never, even by accident, touching any of them. These marvellous results led him to believe that these animals are endowed with a sixth sense, the immediate operation as well as the locality of which is, of course, unknown to and unappreciable by us: but the sagacity of Cuvier* removed the mystery without weakening the interest of these curious facts, by referring to the flying membrane as the seat of this extraordinary faculty. According to this view of the subject, the whole surface of the wings on both sides may be considered as an enormously expanded organ of touch, of the most exquisite sensibility to the peculiar sensation for which it is intended; and it is, therefore, by the varied modification of the impulsion of the atmosphere upon this surface, that the knowledge of the propinquity of foreign bodies is communicated. This membrane is every where furnished with oblique or transverse bands, consisting of lines of minute dots resembling in some measure strings of very small glands or cutaneous follicles. May there not be some connexion between these peculiar little bodies and the extraordinary function just described?

* Leçons d'Anatomie Comparée, t. ii. p 582.

The tendency to an extraordinary development of the dermal system is not confined to the organs now mentioned, of the senses of touch and of hearing. The *organ of smell* is in many insectivorous Bats, as in the whole family *Rhinolophidæ*, furnished with foliaceous appendages, formed of the integument doubled, folded, and cut into the most curious and grotesque forms. These nasal leaflets are found principally or exclusively to belong to a group, the habits of which are more completely lucifugous and retired than any others; they are found in the darkest penetralia of caverns, and other places where there is not even the imperfect light which the other genera of Bats enjoy. It is probable that this development of skin around the nose is intended to give increased power and delicacy to the organ of smell, as well as to regulate the access of the odoriferous particles, and thus to supersede the sense of vision, in situations where the latter would be unavailable.

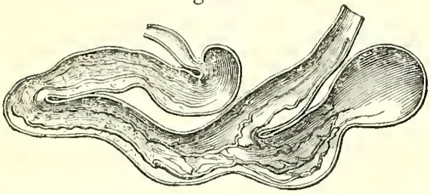
In the genus Nycteris a curious faculty is observed, namely, the power of inflating the subcutaneous tissue with air. The skin adheres to the body only at certain points, where it is connected by means of a loose cellular membrane; it is therefore susceptible of being raised from the surface, on the back as well as on the under parts. These large spaces are filled with air at the will of the animal, by means of large cheek pouches, which are pierced at the bottom, and thus communicate with the subcutaneous spaces just mentioned. When the animal therefore wishes to inflate its skin, it inspires, closes the nostrils, and then contracting the cavity of the chest, the air is forced through the openings in the cheek pouches under the skin, from whence it is prevented from returning by means of a true sphincter, with which those openings are furnished, and by large valves on the neck and back. By this curious mechanism the bat has the power of so completely blowing up the spaces under the skin, as to give the idea, as Geoffroy observes, " of a little balloon furnished with wings, a head, and feet."

The digestive organs of the Cheiroptera exhibit as distinct a division into the two principal groups before-mentioned, as any other part of their anatomy. The teeth have been already alluded to, and the characters of these important organs, important as indicating, in the most unerring manner, the nature of the food, are well-marked in the two groups. The flattened crowns of the molares, so similar to those of the Quadrumana which are found to belong to the frugivorous Bats, are strikingly contrasted with the many-pointed tuberculous teeth of the insect-feeders, and exhibit an interesting affinity to the two important orders of animals to which the Cheiroptera may be considered intermediate; the former division referring evidently to the Quadrumanous type in the structure of the teeth, and the latter to the type of the *insectivora*.

The tongue presents a peculiarity in the genus Phyllostoma, which is worthy of being particularly noted. It consists of a number of wart-like elevations, so arranged as to form a complete circular suctorial disk, when they are brought into contact at their sides, which is done by means of a set of muscular fibres, having a tendon attached to each of the warts. By means of this curious sucker, these bats are enabled to suck the blood of animals and the juice of succulent fruits. This power has been attributed by mistake to some of the genus Pteropus, merely because their tongue is rough, and it was calculated that by means of such a surface the skin may have been abraded.

The stomach is no less indicative of the nature of the aliment than the teeth; offering, in the *Pteropus* (*fig.* 287), a very striking affinity to that

Fig. 287.



of many true vegetable feeders in some remote orders, and in *Plecotus* (*fig.* 288), as complete

Fig. 288.

an identity with that of the carnivorous type. In the former the œsophagus swells out before it enters the general cavity, and that dilatation, as Home observes, appears, from its structure, to belong to the stomach. To the left of the œsophagus there are two dilatations, the farthest of which has a smooth surface and thin coats; the other is furnished with several deep longitudinal rugæ, some of which are continued from similar ones in the œsophagus. Four of the rugæ are continued towards the pylorus, giving a direction to the food in that course; about one-third of the stomach towards the pyloric extremity is turned back upon itself, and the pylorus is consequently placed externally close to the entrance of the œsophagus. At the pylorus is a very small opening into the intestine, which when contracted seems scarcely pervious to air. Such is the complicated form of the stomach in the frugivorous division; whilst that of the insect-feeders is as simple as possible, being only divided into a cardiac and a pyloric portion with scarcely the slightest contraction. *The intestines* present a no less marked distinction. In the *Pteropus* they are no less than seven times the length of the body, whilst *Vespertilio noctula* offers the shortest proportional length of the canal, it being only twice as long as the body. The latter is also wholly devoid of a *cæcum*.

The organs of generation.—The male organs of the Bats bear a near relation to those of the Quadrumana and of Man, in some striking respects. The penis is pendulous, and the proportions between the different organs are not very dissimilar; but the testes do not descend from the abdomen excepting during the breeding season, when they are found on each side of the anus, whilst the large epididymis is seen just behind them, on each side of the origin of the tail. The *vesiculæ seminales* are of moderate size, and consist of two round white sacs, which are perfectly simple, forming each a single cavity with a secreting internal surface. They have a *prostate gland*, which surrounds the whole circumference of the urethra, and appears to be composed of numerous small lobes. They have also *Cowper's glands*. The *penis* is very similar to that of the other more highly organized forms, the Quadrumana and Man. It is of moderate size, pendulous, and supported by ligaments, as in the other cases. There is a small bone of the penis. The muscular portion of the urethra is rather long. The glans is in some species enlarged by a small process or button on each side; the urethra opens at the extreme point.

The female organs offer nothing very particular. The *vulva* is round, and exhibits a slight appearance of a *clitoris* near its edge; the mouth of the *uterus* stands out into the vagina. The uterus is two-horned and the horns are very short.

There are but two teats, which are placed on the breast. The additional ones said to exist in the groin of the *Rhinolophi* are most probably ordinary cutaneous glands, as Kuhl could discover no trace of mammary glands beneath them. They were first discovered by Montagu in this country, and by Geoffroy in France.

The Bats are among those animals in whom we notice the remarkable phenomenon of Hybernation, of which it is unnecessary to say any thing here, as a distinct article is devoted to the subject. (See Hybernation.)

For the Bibliography see that of Mammalia.

(*T. Bell.*)

CHYLIFEROUS SYSTEM (in Comparative Anatomy) is that portion of the vascular system of vertebrated animals which is destined to convey the nutritious part of the food, or the *chyle*, from the alimentary canal into the sanguiferous vessels. The function of these chyliferous vessels appears to be performed by the veins in the invertebrated classes, where the white colour of the blood causes them to resemble more closely the lacteals or chyliferous vessels of vertebrata. Several parts, however, of the invertebrated animals have been taken by anatomists for this lacteal system, as the nervous system of Mollusca by Poli, the biliary tubuli of Insects by Sheldon, the mesenteric vessels of Echinodermata by Monro, the radiating prolongations from the stomach of Medusæ by Carus. The chyle of vertebrata, derived from the chyme of the digestive canal, and much resembling the white blood of the lower divisions of the Animal Kingdom, varies in its physical properties and chemical composition in the different tribes of animals, and in the same animal according to the kind of food on which it subsists, (see CHYLE,) being most allied to red blood in the highest animals and those which subsist on the most nutritious animal food, and being most remote from that condition in the lowest fishes and the most imperfect animals. The vessels which convey, and still further elaborate, this fluid, the chyliferous system, like the other systems of the body, present very different grades of development in the different classes of vertebrata.

In fishes they consist of simple vessels in which we cannot separate the two usual tunics; they are destitute of internal valves and mesenteric glands, they form two strata of vessels between the coats of the small intestine, and they convey a limpid chyle to the receptaculum chyli, from which it is sent by one or two thoracic ducts to the branches of the superior cava or the jugular veins. They communicate freely with the veins, they already present numerous constrictions as rudimentary valves, they present valvular orifices at their entrances into the veins, and their numerous convoluted plexuses supply the place of mesenteric glands.

The chyliferous vessels are nearly in the same condition of development in the amphibia, where they form two layers on the parietes of the alimentary canal, are destitute of conglobate glands, form plexuses on the extended mesentery, and terminate in two thoracic ducts which proceed forwards along the sides of the vertebral column. (See AMPHIBIA.)

In the class of reptiles the lacteals present a more advanced stage of formation, chiefly in the development of the internal valves in the trunks and branches in all these animals, and in the white milky condition of their contents in the crocodilian family. (See REPTILIA.) They are still without mesenteric glands, their valves are less perfect than in birds and quadrupeds, and the chyle is still limpid and colourless in the serpents, lizards, and tortoises. The coarse vegetable food of the chelonia, and the great length of their small intestine, give occasion for the numerous large chyliferous vessels which cover their alimentary canal and mesentery. The place of mesenteric conglobate glands is yet supplied, as in the inferior vertebrata, by numerous complicated networks of lacteal vessels, formed in different parts of their course; and, as in fishes, two or more ducts are here observed passing forwards from a single wide receptaculum. The thoracic ducts form numerous free anastomoses with each other in their course forwards to the neck, accompanying the left branch of the aorta to the anterior part of the trunk, where they pour their contents into the jugular or subclavian veins, or into the angle between these vessels. Before entering the veins these ducts receive the lymphatic trunks, as in other classes, from the head and arms. The chyliferous vessels of the chelonia coming from the outer and inner layers spread on the small intestine, unite into considerable trunks, which pass along the mesentery in close proximity to the bloodvessels. The thoracic duct of the tortoise surrounds and almost conceals the trunk of the aorta by its numerous large anastomosing branches.

The inferiority of the chyliferous system of birds to that of quadrupeds is seen even in the properties of the chyle, which is still, as in the lower tribes of vertebrata, a thin, colourless, and limpid fluid. The lacteal vessels are now, however, more obvious, and more regular in their distribution, and are spread in more crowded layers above the mucous and above the muscular coats of the intestine. They collect from the intestine and form numerous anastomosing plexuses on the mesentery, in place of the conglobate glands of mammalia, and then proceed, with the lymphatics, to the receptaculum, which sends forward two thoracic ducts to terminate, on each side of the neck, at the junction of the subclavian with the jugular veins. (See AVES.) The coats of the lacteals are still very thin and distensible in birds; their valves, which are more abundant on the trunks and branches than in reptiles, are still so incomplete as to allow injections to pass easily against their course, and although conglobate glands are not yet developed on the chyliferous system, they are already perceptible on the lymphatics, especially in the neck.

The chyliferous system of the mammalia, though more developed than that of all the inferior classes, is still imperfect as a hydraulic apparatus when compared with the sanguiferous system. The lacteal and lymphatic systems may still be regarded as mere appendices of the venous, performing the functions which are assigned to veins in the invertebrated classes, and serving as inlets to the materials which renovate the blood. No pulsating sacs have yet been detected in the lymphatic system of quadrupeds, nor any distinct motion in the lacteals, the receptaculum, or the thoracic duct. The chyliferous system of this class presents a superiority of development in the almost sanguineous characters of the chyle, in the more perfect structure of the vessels and their valves, in the development of the conglobate mesenteric glands, in the frequent unity or concentration of the thoracic duct, and in the more isolated condition of this system from the sanguiferous. The mesenteric glands are chiefly confined to the mesentery of the small intestine; they are generally placed apart from each other; sometimes they are united into a *pancreas Asellii;* they are firm in texture, highly vascular, and composed of convoluted lacteals, like more concentrated forms of the plexuses of the lower vertebrata.

(R. E. Grant.)

CHYLIFEROUS SYSTEM (Human Anatomy). See LACTEAL.

CICATRIX. (Fr. *Cicatrice;* Germ. *Narbe.*) When from accident or disease a portion of any organ in the body has been destroyed, a process is set up by Nature for the repair of the breach, a new structure is generated, which possesses many properties of considerable interest and importance both in a physiological and a pathological view. The new formation constitutes what is termed a cicatrix, and the process by which it is completed, the process of cicatrization. We shall in this article give a general view both of the mode of of repair and of the product when completed.

The restorative process, when a part of the skin has been destroyed, is extremely interesting. The first stage varies according as the part is removed at once, as by excision, or secondarily, as by sloughing. The immediate effect of removing a portion of skin is, that the surrounding integument, by its inherent elasticity, retracts, and to a certain extent, enlarges the breach made by the wound. In a short time after the infliction of the injury inflammation and suppuration take place. As the next step, fibrine is effused, which very shortly becoming organized, constitutes those red, soft, roundish elevations known by the name of granulations. As these form, a contraction of them occurs, by which the edges of the sore, which had at first retracted, are now brought back again towards their original situation.

John Hunter informs us that this contracting tendency in the granulations is in some degree proportioned to the general healing disposition of the sore, and the looseness of the parts on which the granulations are formed, for when there is not a tendency to skin, the granulations do not so readily contract.* The contraction continues till the whole is healed over, but its greatest effect is at the beginning; one cause of which is that the resistance to it from the surrounding parts is then least.

While this is going on within the circumference of the sore, and immediately preceding the commencement of actual cicatrization, the surrounding old skin, close to the granulations, becomes smooth and rounded with a whitish cast, as if covered with something white, and the nearer to the cicatrizing edge, the more white it is. At this moment the process of cicatrization is actually beginning, and the new cuticle may now be observed to be spreading from the circumference of the sore towards the centre, not uniformly, but creeping irregularly over the granulations, or rather formed irregularly from them, but always, in recent sores, spreading in a continuous surface from the circumference. In large and old ulcers, however, in which the edges of the surrounding skin have but little tendency to contract, or the cellular membrane underneath to yield, the old skin also having but little disposition to skinning in itself, the nearest granulations do not receive from it a cicatrizing tendency. In such cases new skin forms in different parts of the ulcer, standing upon the surface of the granulations like little islands. The rapidity with which the skinning process takes place in this stage is but an uncertain criterion whereby to judge of the time that will be occupied in the cure. Generally speaking, the latter stages of the process are much slower than the earlier, particularly when the breach of surface has been large.

And here a question arises: is the new skin that is formed the result of an altered state of the granulations themselves, or is it an entirely new product from them? Bichat inclined to the former opinion, holding that the granulations having discharged their fluid contents, collapsed, and uniting one to another, became converted into the uniform smooth membrane in question. Hunter, on the contrary, considered the new cutis as a new product, the secretion of the granulations. Our own observations lead us to adopt the opinion of Bichat. It seems that, as soon as the surface of a granulation is covered over with epidermis, which is often the case before the least shrinking or collapse of the granulation occurs, then the secreting orifices of those numerous vessels of the granulation which had hitherto been pouring out pus are now sealed up, and having no longer any use, the same change takes place which occurs in other parts of the system similarly circumstanced: an organ no longer in use shrinks and the fluid parts become absorbed, and the elevated soft and spongy granulations shrink into the thin and somewhat dense fibrous structure of the cicatrix. We cannot agree with the opinion of M. Dupuytren, that the chorion is formed first, and the epidermis added subsequently, since we have often detected the epidermis creeping over granulations so little altered in appearance that its presence could only be discovered by placing the part in such a light that its dry shining surface could be distinguished from the soft villous appearance of the neighbouring granulations. The process of contraction, we believe, generally, if not always, does not precede but follows the formation of the cuticle, and consequently the cutis formed by this contraction does in the order of time follow the cuticle. The reason of this we cannot explain, but of the fact we cannot doubt; and this fact accounts for the very slow formation of the cuticle in the first healing of an ulcer where that membrane is formed from the granulations. The organization of these bodies may be said to be much inferior to that of the cutis when completed; hence, when the cuticle of a cicatrix is abraded, it is readily formed again, because it has now a more perfect organ to secrete it.

As the new cuticle covers the granulations, then, these two striking changes immediately take place in their state; the secretion of pus is stopped, the surface becoming dry, and that process of shrinking or contraction begins which we shall find to continue for a considerable period after the whole sore is apparently

* On the Blood, 8vo edit.

healed. The contractile action takes place in every direction, producing that depression of the cicatrix which is observed to follow the spreading of the cuticle over the granulations. Thus those parts which were soft and spongy now acquire firmness, and form a condensed layer, which occupies the position, and performs some of the functions of the original cutis which had been destroyed.

It is an interesting question, why the cuticle in covering an ulcer, though evidently formed from the granulations, is arising not over the whole surface of the ulcer at once, as it is when abraded from the healthy skin, but creeps from the circumference towards the centre, in a slow, progressive manner? It seems that a greater perfection of organization is necessary for the production of cuticle than for the formation of granulations capable of secreting pus. If we examine the vascular structure of these newly formed parts, we find that the bloodvessels apparent on the granulations are few and very irregular in their course, and often in figure also, having an appearance resembling a varicose or unequally dilated state; this we take to be an indication of a feeble and incomplete state of organization. On the contrary, the vessels in the immediate vicinity of the new skin, are more regular in form and direction, and may often be seen running onwards through the neighbouring granulations towards the centre of the sore, having a good deal the appearance of the vessels of the inflamed cornea; and where this is not remarkably apparent, the granulations in the immediate neighbourhood of the parts in which the skinning process is going on are more vascular than the internal ones. Our observations would lead us to believe that this more perfect system of circulation commences by an anastomosis newly set up from the vessels of the edge of the healthy skin first, and by the action of these newly formed vessels the cuticle is secreted. From these, others are still sent on over the surface of the sore, or immediately under it, and thus by progressive steps the necessary degree of perfection of structure is acquired, and is immediately followed in its progress by the development of the cuticle. This, be it remembered, is still a different state of the granulations from the contracted unsecreting layer which constitutes the new chorion. If this description of the process is consistent with Nature, it is reasonable to suppose that the new vessels shooting from the edges of the healthy skin would be more perfect, and more equal to the task required than those which would pass through the granulations from the subjacent cellular tissue; and in the same way we may suppose that one part being in the before-mentioned manner completed, is better fitted to send on new vessels for the organization of the next portion of granulations than the granulations themselves. It is moreover to be expected that the power of organizing its neighbouring parts must be superior in the healthy skin to that of any newly formed structure, and that this power will in an extensive sore gradually diminish as the distance from the healthy parts increases; and this accords with the well-known fact that the cicatrization goes on much more slowly in the latter stages of healing than at the commencement

Thus the external process of skinning is completed, but the internal changes are not yet finished. A slow but remarkable change is going on for a considerable time longer, by which the appearance and structure of the cicatrix becomes modified. From a red colour it becomes gradually paler, till it is almost white; this at least is the general rule, though under circumstances, to be presently mentioned, the result is different. The cicatrix also continues to contract in all its dimensions, thus not only diminishing in extent, but sinking below the level of the surrounding skin, and becoming more dense and thin and more perfect in its organization, till it has assumed the appearance and character which it will retain through the rest of life.

It is this power of contraction resident in the new chorion of the cicatrix, that produces those bridles which are such frequent causes of deformity after the healing of extensive burns. In these cases there does not seem any necessity to have recourse to any peculiarity of hypothesis in explaining the great degree of shrinking that so commonly occurs. On the contrary, we conceive that the phenomena attending the healing up of burns are to be accounted for by means of the usually recognized causes of the shrinking in the cicatrices of wounds in general.

We have now described the process of repair in wounds in the skin, with loss of the entire substance of the cutis. When the destruction has been more superficial, the process of restoration is more rapid, and the result more perfect, inasmuch as the part upon which the burden of repair devolves, is the inner layers of the original cutis, a part much more highly organized and more equal to the task than the cellular tissue.* In wounds which are united by the first intention, the stage of suppuration does not take place. The substance which would have formed suppurating granulations here becomes an immediate means of union, and the only portion of new skin formed is in the mere line where the divided edges met, a line always visible by the white colour before mentioned.

In the healing of ulcers in any of the mucous membranes, the process would appear to go on much in the same way as on the skin. Granulations shoot up from the bottom of the ulcer; the surrounding healthy membrane is drawn inwards by their contractile power, and the edges of the ulcer are turned in and become continuous with the new membrane, which at length covers the ulcer. When the destructive process has merely gone through the mucous membrane, the granulations shoot from the muscular coat, and the contraction is of course exercised only upon the surrounding mucous coat; but when the muscular tunic is destroyed, the

* See Hunter on the Blood, 8vo edit. p. 274.

granulations grow from the bottom of the wound, that is, from the cellular tissue in contact with the peritoneum; but the contraction of the surrounding parts now diminishes the circumference of the ulcer very considerably by puckering up this thin layer of membrane, so as to give it externally an appearance as if a small portion of the intestine had been taken up by the forceps and tied with a ligature on the inside.* When the process of repair is completed, a fine web-like production from the edges of the ulcer overspreads its base, and forms fine wrinkles converging towards its centre. This production is destitute of villi, and slightly depressed. When the ravages of the disease have been very extensive, the cicatrix is covered by puckered cellular tissue, formed of white thread-like filaments, crossing each other in all directions, and leaving pitted interstices.† When the ulcer was small, the cicatrix has sometimes a considerable resemblance to the scar of small-pox.‡

That cicatrization takes place in the lungs after tuberculous excavations, the observations of Laennec § and Andral || among others, have put beyond a doubt; and since these pathologists have made public their observations of the fact, and pointed out the signs by which it may be known, most observers have borne testimony to the accuracy of their statements. According to Laennec there are three ways by which this desirable object is accomplished; one, by the walls of the cavity becoming lined with a membrane of a semicartilaginous structure and smooth polished surface, which seems often continuous with the lining membrane of those bronchial ramifications which open abruptly into the cavity. This state of the restorative process constitutes a sort of internal cicatrix, analogous to a fistula, and is in many cases not more injurious to health than the species of morbid affection just mentioned. The second mode of cicatrization consists in the obliteration of the morbid cavity by adhesion of its sides. In the complete state they exhibit, when cut into, a band of condensed cellular substance or of fibro-cartilaginous structure. The bronchial tubes which run towards this structure are obliterated as they reach it, and there is generally an unusual quantity of the peculiar black matter of the lungs in the parts bordering upon the cicatrix; and where this is the case, the structure of the lungs is more flabby and less crepitous than natural. These internal cicatrizations are indicated on the surface of the lung by a depression of the pleura, the depth of which corresponds with the size of the previous excavation, and is sometimes so deep as to form a large overlapping prominence of the neighbouring sound parts. Here we have another instance of the same contractile tendency in newly formed structures, which is so striking in cicatrizations of the skin; a tendency resulting from the general law by which the labour of restoration is, as much as possible, spared to the animal system.

The third species of cicatrix in the lungs is that formed by the fibro-cartilaginous walls increasing in thickness till they fill up the cavity, thus leaving a blueish or greyish white mass, in which large bronchi terminate abruptly as in the preceding case. Cicatrices of the two last kinds are not uncommon.*

In the healing of common abscesses, whether in the subcutaneous cellular tissue or in the more deep-seated parts, the mode of cicatrization is much the same as in the second species just described. As the fluid contents are removed by evacuation, the cavity of the abscess is diminished in extent partly by the contraction of the surrounding tissue and partly by the granulations arising from the sides of the cavity, and as the opposite sides are thus brought in contact they adhere, and at length leave a fibrous cicatrix, whitish and more dense than the surrounding cellular tissue. It is remarkable that few or no abscesses granulate till they are exposed, and that after they are opened there is one surface that is more disposed to granulate than the others, which is the surface next the centre of the body in which the suppuration took place. The surface next the skin hardly ever granulates, but on the contrary has an ulcerative tendency The proximate cause of this remarkable difference is not evident, but the utility of it in the healing of the abscess is clear and striking.†

We have now considered the processes by which nature repairs the breach in the healthy structure; let us in conclusion shortly examine the characters which mark the cicatrix when completed. This new formation, though in many points it resembles and fulfils the functions of the old and perfect skin, yet differs from it in many material respects.

1. It occupies, as we have stated, a smaller space, having by its contraction drawn the surrounding skin inwards, and thus, by the wise economy of nature, diminished the surface requiring new skin to cover it. This is of course most strikingly seen in those parts where the cellular texture is loose and yielding, as in the scrotum, where a large loss of skin is often healed with only a very small cicatrix. On the contrary, parts that cannot so yield are healed with a proportionately large cicatrix, as in wounds of the scalp, &c. 2. The texture of the cicatrix is frequently harder and thicker than the natural skin. This circumstance varies considerably, but we believe this variation will be found to bear a pretty exact relation to the degree of contraction, to the length of time occupied in the cure, and to the irritation to

* Dr. Latham on the Disease of the General Penitentiary, p. 51.

† Dr. Hope's illustrations of Morbid Anatomy, vol. i. p. 203. See also Billard's Recherches d'Anat. Pathol. p. 534.

‡ Bright's Medical Reports, vol. i. p. 182, where are some very interesting illustrations of this portion of pathological anatomy. See also on this subject a valuable paper by M. Troillet in the Journal Gén. de Médecine. Reported in the Med. Chir. Rev. vol. v. p. 192.

§ On Mediate Auscultation, translation by Dr. Forbes, 2d edit. p. 300.

|| Clinique Médicale, tom. iii. p. 382.

* See Hope's Illustrations of Morbid Anatomy, vol. i. p. 34.

† Hunter on the Blood, p. 593.

which the ulcer was subjected in the process of healing. When these have been considerable, the hardness is correspondingly great, while, if the cure has been expeditious and the part been kept extended and irritation avoided, the cicatrix remains soft, thin, and pliable, a point of great importance in practice as applied to the healing of burns. 3. The colour of the new skin is different from the natural parts. This arises from the want of rete mucosum, which is not regenerated till long after the other tissues, and sometimes not at all. For this reason a cicatrix in a Black is as white as that in an European; but after a considerable lapse of time, this structure is sometimes formed anew, and in some instances becomes even of a darker colour than before. 4. The surface is perfectly dry from the want of exhalent pores, which are never found to be restored even in the oldest cicatrices. Indeed, in cases where the chorion has not been destroyed through its entire thickness, the loss of substance reaching only through its outer layers, these porcs are generally obliterated, and the important exhalent function of the skin is annihilated; and even when the injury has extended only through the external vascular structure of the skin, as is the case in the healing of a blister which has been long inflamed, we have observed a drier state of the parts, and more polished than the surrounding skin which had not been injured. From this peculiarity in the cicatrix, when the whole body is bathed in sweat these parts are dry and polished. This state of dryness, however, partly results from another anatomical deficiency, namely, of the perspiratory glands, which are destroyed in cases where the entire integument has been injured, and these are of course never regenerated. 5. The new tissue contains no hairs, and if, after superficial wounds, a few scattered hairs appear on the surface, they are feeble and white. 6. After the healing of a large ulcer of long standing, the new surface is sometimes much lower than the surrounding skin. Nature seems, in these cases, to have exhausted her energies in the long endeavour to heal the ulcer, and the granulations never rise to the level of the surrounding skin, as in recent cases. The new cuticle therefore commences upon those granulations which shoot from the elevated edges of the ulcer, and the cicatrizing process is thus led as it were into the hollow of the ulcer, and spreads along its surface, completing the cicatrix in an excavated form. 7. The elasticity of the cellular tissue under the new chorion is less than that of the ordinary cellular web; nor does it allow of distension to the same degree. This is seen in œdema and emphysema, where this part will often remain depressed while the surrounding parts are raised and distended; it is also seen in the impediments which large cicatrices prove to the movements of the joints. The same circumstance perhaps also gives a reason for there being no fat contained in these parts. This want of extensibility seems to be but one consequence of the law which regulates the products of inflammatory action. The elastic power is materially diminished in the natural cellular tissue by inflammation, a degree of stiffness and difficulty of movement remaining for a long time after; and as the tissue of a cicatrix is, *ab initio*. the product of inflammatory action, it is to be expected that it should shew the same effects.

How far are the vascular and nervous functions of the lost part restored in the cicatrix? It is probable that the new structure receives nerves, but in small number. Of those senses which can be implicated in the destructive process of ulceration, that of touch alone seems to be restored. This is so in a marked though still imperfect degree, the sensation in these parts being somewhat of that dull kind experienced after paralysis.

On the temperature of the cicatrix we have not made sufficient observations to generalize, but we have found that the actual temperature of the bridle from a burn, while it retains its hardness, is several degrees above that of the healthy skin, while the power of retaining its temperature, or of resisting the extremes of heat and cold, is much inferior in the cicatrix to that which the healthy skin possesses, although the actual temperature, *under ordinary circumstances*, is the same as the surrounding skin. Almost every traveller to the Poles or to the Tropics mentions the liability of old ulcers that had been healed, to announce the extremes of temperature by pain and inflammation.

The bloodvessels of the new structure are at first numerous, as indicated by the redness and the readiness with which it bleeds, but afterwards they diminish much in size and number, so that, in an old cicatrix, it is often impossible to force an injection into them. M. Dupuytren tells us that in scars upon the face the greatest heat from exercise, or the influence of the mind in producing blushing, leaves this part uncoloured amid the surrounding redness.* Bichat assures us that even the new epidermis itself is overrun with bloodvessels.† We have certainly never been able to discover the least trace of vascularity in it, nor have we found that sensibility in this part which he describes. It seems to be a matter of doubt at present how far the function of secretion exists in the new production. Dr. Bright seems to believe in its restoration, since he says that the scar in one of his observations appeared to be covered with a true mucous membrane; but it is right to state that the proof he gives of this is rather equivocal, namely, that the surface was quite continuous with the membrane lining the rest of the canal; "indeed," he adds, "when inspecting the ulcer in the process of healing, we perceive the vessels of the mucous membrane running over the surface to be repaired."‡ M. Troillet mentions in round terms that the cicatrix had the thickness, consistence, and appearance of mucous membrane;§ but neither he nor Dr. Bright says any thing in particular as to the villous structure, which we conceive to be an essential characteristic of some forms of

* Leçons de Clinique Chir. tom. ii. p. 47.
† General Anatomy, Transl. vol. ii. p. 899.
‡ Med. Reports, vol. i. p. 182.
§ Med. Chir. Rev. vol. v. p. 194.

mucous membranes.* Dr. Hope's and M. Billard's cases were destitute of villi, and the latter expresses a doubt whether it ever takes place. Our own observations decidedly incline us to the same opinion.

Like all adventitious organic products, cicatrices are very readily irritated and are destroyed by ulceration with amazing rapidity. A few days and even a few hours are sometimes sufficient to undo the restorative labours of many months; but this destruction is often superficial, and then the after-healing is as rapid as the previous ulceration.

M. Dupuytren† informs us that the cicatrix resulting from an entire destruction of the skin is not liable to be affected by many exanthematous diseases, such as scarlet fever, measles, and small-pox; it remains pale in the midst of the inflammation and eruption which covers the neighbouring parts. The contrary takes place only in superficial cicatrices, under which some layers of the original cutis exist, and which participate in the properties as well as in the inflammatory tendencies of the rest of the skin.

In conclusion we may state, that it appears, from the previous considerations, that in the repairing of the injuries in question, beautiful as is the process and useful as are the results, yet nature's great object does not consist so much in an endeavour to restore the lost structure in all its functions and perfections of organization, as merely to produce a covering for those parts which remain uninjured, to act as a defence to them from external irritations and injuries, and possessed therefore only of such a degree of vitality and of such properties of structure as shall be sufficient for its own preservation and repair.

(A. T. S. Dodd.)

CILIA,‡ (in anatomy, Fr. *Cils;* Germ. *Wimperhaare.)* This term is used to designate a peculiar sort of moving organs, resembling small hairs, which are visible with the microscope in many animals. These organs are found on parts of the body which are habitually in contact with water or other more or less fluid matters, and produce motion in these fluids, impelling them along the surface of the parts. The currents or other motions thus produced serve various purposes in the economy of the animals in which they occur. In other circumstances the cilia serve as organs of locomotion, some aquatic animals propelling themselves through the water by their means.

Cilia have now been ascertained to exist in a great many invertebrated and in all vertebrated animals, except Fishes;§ having been very recently discovered by Purkinje and Valentin on the respiratory and uterine mucous membranes of Mammalia, Birds, and Reptiles.

The terms "vibratory motion" and "ciliary motion" have been employed to express the appearance produced by the moving cilia; the latter is here preferred, but it is used to express the whole phenomenon as well as the mere motion of the cilia.

A considerable space has been allotted to the present article, more perhaps than its relative importance may seem to demand, chiefly for the reason that, with one exception, no attempt has been hitherto made to collect and describe under appropriate heads, the facts known on the subject. The exception alluded to is a work by Purkinje and Valentin,* which appeared while this article was in progress, and which contains not only an account of their own discovery, but a history of all preceding observations. But the manner of treating the subject in the work alluded to is for the most part so different from that which is here followed, that its publication has not seemed to warrant any material abridgement of the following article, which, on the contrary, it has increased by affording much new and important matter, as will be acknowledged in its proper place. Another ground on which indulgence may be claimed for details which are, perhaps, greater than may seem commensurate with the importance of the subject, is that many of the facts are here described for the first time, and it was felt desirable to state them in their full extent, which could not be done intelligibly without considerable length of description.

The article is divided into two parts; the first comprehends the particular facts, or an account of the phenomena as they occur in the different tribes of animals considered in Zoological order, with the history of their discovery; the second part consists of general deductions from the first, and also treats of the structure and mode of action of the cilia in general. This method has been adopted as appearing on the whole best suited to the present state of knowledge on the subject.

PART I.

1. *Infusoria.*— Cilia exist very extensively in the different tribes of Infusory Animalcules; indeed they constitute the principal organs of motion in these small animals. When a drop of water containing Infusoria is brought under the microscope, these creatures are seen swimming rapidly through it in various directions; and as they move along, small particles of foreign matter which happen to lie near their path are thrown into agitation, obviously indicating the existence of currents in the neighbouring water. When the animals remain steady in one place, these currents become much more distinct, setting in particular directions, and causing the small particles to run in a stream to and from the animal. If the magnifying power be sufficiently strong, small transparent filaments will be distinguished, projecting from the surface of the animalcules and moving in a very rapid manner. These are the cilia; they serve like fins or paddles to carry on the animal in its progression through the water, and when it is stationary, they impel the water in a current along the surface, which

* Med. Chir. Rev. vol. x. p. 324.

† Op. cit. tome ii. p. 48.

‡ For another signification of this term, see the articles EYE and LACHRYMAL APPARATUS.

§ Fishes are no longer an exception; see note at page 632.

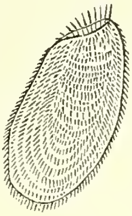
* De phenomeno motus vibratorii, &c. 4to. Wratisl. 1835.

is beset with them. They may be often most distinctly seen when their motion becomes languid or impeded, as is the case when the water round the animal is diminished by evaporation to such a degree as not to afford scope for their full and rapid play.

The cilia of the Infusoria in their arrangement are either separate and independent, or combined, forming in the latter case the rotatory or wheel-like organs of the rotiferous tribes of animalcules.

In the first or simple form, which exists in the Polygastric Infusoria (*fig.* 289), the cilia are usually set round the mouth or spread over the body generally, in which case they are often disposed in regular rows. Their structure has been carefully investigated by Professor Ehrenberg, who states that each is furnished with a bulb at the root, to which minute muscles are attached. A slight degree of rotation communicated to the bulb causes a much more extensive motion in the rest of the organ, which in its revolution describes a cone. From time to time the animal sets its cilia in motion, and then, if its body be free, the cilia, acting like fins or oars, move it onwards through the water, serving in this case as organs of locomotion. If the body is fixed, the cilia communicate an impulse to the surrounding water and excite a current in it. This may always be made evident by mixing with the water some colouring matter, the particles of which are hurried along by the current. Many of these particles are conveyed towards the mouth, where some are swallowed and the rest thrown back, the cilia in this case serving the animal as a means of seizing its food.

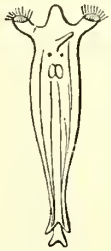
Fig. 289.



Leucophrys patula.

In their combined form the cilia constitute the singular and well-known rotatory or wheel-like organs of the Rotiferous Infusoria. These are formed of one or more circles of cilia, placed on the fore part of the animal, as in Philodina (*fig.* 290), in which the organ is double, consisting of two circles of cilia set on two short processes, one on each side of the mouth. This apparatus can be retracted or pushed out at the will of the animal. When in motion, the circles of cilia have the appearance of toothed wheels turned round on their axes, first in one direction and then in the opposite. Various explanations of this apparent revolution have been given. According to Ehrenberg it is an optical deception, which he thus explains: the individual cilia composing the rotatory organ move in the same manner as the separate cilia above mentioned, that is, they each revolve in such a way as to circumscribe a conical space. When viewed sideways, in performing this revolution they must necessarily pass at one moment a little nearer, at another a little more distant from the eye, or, in other words, become alternately more and less distinct to the view at short intervals; and this alternation occurring over the whole circle gives rise to a seeming change of place in every part of it, and a consequent appearance of rotation. Perhaps it would be an equally satisfactory and a more simple explanation to consider the appearance as occasioned by an undulatory motion of the cilia, such as that produced by the wind in a field of corn; the undulations following one another in every part of the circle would give the appearance of rotation. Such a waving motion of the cilia undoubtedly occurs in other animals. The Rotifera set in motion or retract their ciliary organs apparently by a voluntary act; they use them for similar purposes as other Infusoria use their simple cilia; when the body is free, the rotatory organ propels it through the water; at other times the animal fixes itself by its tail, and setting in motion its wheels, produces currents in the water, by means of which it seizes its food. These currents in most of the Rotifera have a determinate and regular direction.

Fig. 290.



Philodina erythropthalma.

The cilia of the Infusoria, then, serve as organs of locomotion; and in the greater number of species they are the only visible organs for this purpose; indeed it is not improbable that they may exist in others in which from their smallness they have hitherto eluded observation; as in such cases currents are observed which are most probably produced by invisible cilia. Secondly, the cilia are employed by the animals in catching their food. Thirdly, it is extremely probable that, by bringing successive portions of water into contact with the surface of the animal, they serve also for respiration.

Soon after the invention of the microscope, the animalcula of infusions became a favourite subject for its employment, and the cilia and the motions which they produced did not escape the notice of the earlier microscopic observers. Leeuwenhoek observed them distinctly and recognised their use, and probably he was the first that did so. He repeatedly makes mention of them in his writings. At one place* he describes them in an animalcule, which seems to have been the *volvox*, as short slender organs projecting a little from the body, by means of which the animal produced a revolving motion and moved onwards. Again,† in speaking of the animalcules which he obtained from an infusion of pepper, he states that these animals produced a great commotion in the water by means of divers organs placed on the fore part of the head, which organs also the animals used in swimming. "In this way," says he, "they occasioned such a circular eddy in the water that not only several

* Continuatio Arcanorum Naturæ, 1719, p. 382, Epist. 144.

† Continuatio Epistolarum, 1715, p. 95, Epist. 17, Oct. 1687.

small bodies floating in the water were moved in a circular manner, but even many very minute animalcules, though able to swim vigorously, when they approached the larger animalcules, were whirled about for some time in a circular manner." In announcing his discovery of the wheel animal,* he describes its rotatory apparatus as two projecting discs set round with very slender elongated organs. "Imagine," says he, "two wheels set round with points of needles, and moved very swiftly round from west by the south to the east." He adds that he cannot comprehend how such motion takes place in a living body. Lastly, in describing a small animal which he found adhering to the water-lentil, (probably a species of vorticella,) and speaking of the currents which it excites, and by which it attracts its food, he adds the following reflection:† "Moreover it is necessary that these animals, and in general all such as are fixed and cannot change their place, should be provided with an apparatus for stirring up motion in the water, by which motion they obtain any matters that float in the water, for their nourishment and growth and for covering their bodies."

Baker,‡ next to Leeuwenhoek, takes notice of the cilia of animalcules. He observed them in many species, and named them fins, or feet, and sometimes fibrillæ. He distinctly recognised the currents produced by them, and inferred the existence of cilia as the cause of visible currents in cases where the cilia themselves could not be seen.§ In particular, he bestowed much pains in investigating the economy of the wheel animal previously discovered by Leeuwenhoek, and addressed a letter to the Royal Society on the subject, in 1744.|| He there describes its rotatory apparatus as "a couple of semicircular instruments round the edges of which many little fibrillæ move themselves very briskly, sometimes with a kind of rotation, and sometimes in a trembling or vibrating manner,"¶——"by this means a current of water is brought from a great distance to the very mouth of the creature, which thereby is supplied with many little animalcules and various particles of matter."** He also states that the wheels are instruments of locomotion by which the creature swims.†† Baker drew a distinction between the rotatory and vibratory motions of the cilia, these organs being moved in some animals in the one way, in some in the other, while in others they seemed capable of being used in both ways.‡‡ It appears that he was aware of the true structure of the so-called wheels, and though he often speaks of their being turned round, he was still doubtful of the reality of the apparent rotation.*

Spallanzani, in his curious and interesting researches on the production and economy of the Infusoria, made observations similar to those of Baker on the cilia and their motions. He describes them as small filaments or points agitated with a vibratory or oscillating motion. He conceived them to be organs of locomotion which the animals used in swimming,* and that they also served to excite a vortex or current by means of which food was brought to the mouth. "The oscillating filaments cause the vortex; the vortex draws the floating particles into the aperture or mouth of the animalcule, and the latter chooses for its aliment the most delicate, or at least those which suit it best."† He afterwards describes the ciliary apparatus of the vorticella in a similar manner.‡ In the account of his singular experiments on the apparent resuscitation of the *Rotifer*, he describes its wheel organs as two circles of filaments, exactly like the vibrating filaments of other Infusoria, which by their continued motion give rise to the appearance of two moving wheels; but he distinctly states that the rotation is only apparent, not real. These organs, he adds, serve the same purposes as the simple cilia.§

Needham,|| about the same time as Spallanzani, correctly observed the cilia, and recognized their uses. Saussure¶ observed the currents, but did not perceive the cilia. Pallas,** in his systematic work on Zoophytes, describes the eddies or currents produced by certain Rotifera, and notices their cilia, but far less clearly than his predecessors. Wrisberg†† observed the currents and eddies produced by the vorticellæ; at least he saw smaller Infusoria and particles of floating matter hurried on towards their mouths, but he seems not to have perceived the cilia.

Otto Frederick Müller,‡‡ in his systematic work on the Infusoria, described the appearance and arrangement of the cilia in each species, and represented them in figures. He named them *cilia* and *pili*, and ascribed to their action the currents and vortices which the Infusoria excite. But while he assigns to them the office of locomotive organs, he denies that they are employed in seizing food; for, what is singular, in his long-continued and elaborate inquiries into the economy of these animals, he could never perceive that foreign matters drawn into the mouth were retained there as nourishment, but believed that they were always again thrown out. In this, however, he was undoubtedly mistaken.

* Continuatio Arcanorum Naturæ, 1719, p. 386, Epist. 144.

† Epistolæ Physiologicæ, 1719, p. 66. Epist. 7.

‡ I cite his work entitled "Of Microscopes, and the Discoveries made thereby," London, 1785, although his observations were previously related in separate memoirs of a much earlier date.

§ Of Microscopes, vol. i. p. 71, p. 80.

|| Reprinted in op. cit. ii. p. 267.

¶ P. 271.

** P. 273.

†† P. 284.

‡‡ P. 292.

* Opuscules de Physique, tom. i. p. 180.

† P. 183.

‡ P. 199.

§ Tom. ii. p. 227.

|| Spallanzani, Nouvelles Recherches sur les Decouvertes Microscopiques, &c. 1769, p. 161.

¶ See Letter by Bonnet, in Spallanzani Opuscules, tom. i. p. 176.

** Elenchus Zoophytorum, 1766.

†† Observationum de Animalculis Infusoriis satura, 1765, p. 52, p. 63.

‡‡ Vermium Terrestrium et Fluviatilium Historia, 1773, and Animalcula Infusoria, 1788.

Gleichen,* in 1778, described the currents produced by the vorticellæ. In an earlier work he ascribed an agitation of small bodies, which he had observed in the neighbourhood of one of the Infusoria, to an electric or magnetic force, not having perceived the cilia.†

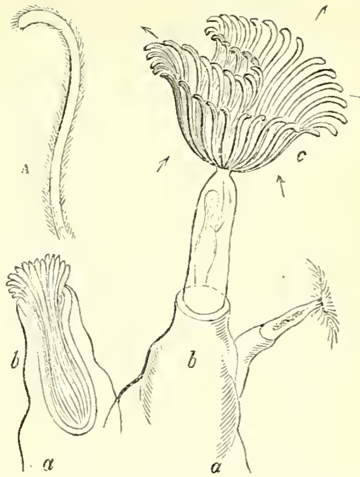
Fontana‡ described the rotatory apparatus of the Rotifer and its use; he conceived that its apparent rotation was produced by the successive elevation and depression of the cilia which encircle it.

Of the more recent writers who have investigated or described these phenomena in the Infusoria, I may mention Dutrochet,§ Gruithuisen,|| Agardh,¶ Raspail,** and Ehrenberg.†† Raspail denies the existence of cilia, attributing their appearance to an optical deception, an opinion which is undoubtedly erroneous. Ehrenberg, who, of all recent observers, has contributed most to the knowledge of the economy and natural history of the Infusoria, has particularly investigated the structure and mode of action of their cilia. The substance of his observations has been already given.

The ciliary motion has been recently observed in the embryo of Infusoria while enclosed in the ovum.‡‡

2. *Polypi and Sponges.—a. Fresh-water polypi.* The phenomena in question have not been discovered in the Hydra, which is the largest and best known of the Fresh-water Polypi; but they have been seen and described by many observers in another sort, viz. that known by the names of the *Polype à panache*, or Plumed Polype of Trembley, the Bell-flower animal of Baker, and Plumatella, Cristatella, Alcyonella, &c. of other naturalists. The Polypes of this kind are connected in groups on a commou stock or stem, (*a*, *a*, *fig*. 291, which represents the animal magnified,) and each is furnished with a tube (*b*, *b′*), into which it can wholly withdraw itself. From time to time they advance a little way out of the tubes and display a double row of arms or tentacula (*c*) ranged round the mouth in the figure of a horse-shoe. When the arms are spread out in this manner, currents appear in the surrounding water, which are made evident by the motion of any small particles that may accidentally or intentionally be suspended in it. The currents pass along the tentacula, the water being drawn towards

Fig. 291.



them from every side, and the main stream at last issues from the midst of them, appearing as if it came out of the mouth, from which, however, it really is not derived. The arms are fringed on their two borders with a multitude of cilia, (see A, a single arm magnified,) set close together, which vibrate in regular succession, their motion appearing like progressive undulations along the tentacula. When one of the arms is cut off, it affects the water in the same way as when connected with the animal, its cilia impelling the fluid in a current, or carrying the separated arm through it, according as it is fixed or free.

As to the use of these motions, it may be stated that they serve undoubtedly for renewing the water in respiration, and probably also to convey food to the animal. Steinbuch, however, remarked that the currents were most lively in pure water, and that the extraneous matters which they conveyed seemed rather to incommode the animal, which endeavoured to avoid them; and from this he inferred that the currents served chiefly if not solely for respiration.

Trembley* and Baker† observed the currents produced by this polype, but both erroneously conceived them to be caused by agitation of the tentacula. Roesel‡ correctly remarked that, during the production of the currents, the tentacula were motionless, but not perceiving the cilia, nor being aware that the arms when detached still produced motion in the water, he supposed that the currents were occasioned by a stream issuing from the mouth. At length Steinbuch§ discovered that separated tentacula retained the power of impelling the water; he distinguished the cilia and their motion as the cause of the impulsion, and

* Abhandlung ueber die Saamen und Infusions Thierchen, 1778.

† See Müller, Infus. p. 87.

‡ Traité sur le venin de la Vipère, etc. 1781, tom. i. p. 87.

§ Sur les Rotifères, Ann. du Musée d'Hist. Nat. 1812, tom. xix. et 1813, tom. xx.

|| Salzburg. Med. Chir. Zeitung, 1818, iv. p. 222.

¶ Ueber die Zauberkraft der Infusorien, Nov. Act. Acad. Cæs. Leop. tom. x. p. 127.

** Hist. Nat. de l'Alcyonella Fluviatile, etc. Mém. de la Soc. d'Hist. Nat. tom. iv. and Chimie Organique, 1833.

†† Abbandl. d. Akad. der Wiss. zu Berlin für 1831.

‡‡ Wagner, Isis, 1832, p. 383.

* Mém. pour servir à l'Hist. d'un genre de Polype d'eau douce, 1744, p. 212.

† Of Microscopes, ii. p. 309.

‡ Inseeten Belustigungen, tom. iii. 1755, p. 458.

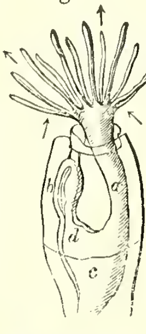
§ Analecten neuer Beobachtungen und Untersuchungen für die Naturkunde, 1802, p. 89.

more correctly described the course of the currents: the foregoing description is in a great measure taken from his memoir. Since then several others* have made similar observations, among whom we may mention Raspail as more particularly deserving of notice, though he here, as in other cases, denies the existence of cilia.

b. Marine Polypi.—The polypi of marine Zoophytes, on which observations relating to the present subject have been made, may for our purpose be conveniently arranged under three principal forms.

The first form of polype (*fig.* 292) is found in Flustræ and cellular polypi generally; it exists also in some species which have been classed among the Sertulariæ, and probably prevails very extensively in different tribes of Zoophytes. The body (*a*, *b*, *c*), which is generally contained in a cell, is bent on itself, somewhat like the letter Y or V; the one branch (*a*) being the mouth and throat, the other (*b*) the rectum opening by an anus, and the middle part (*c*), which is of a dark and often of a brown colour, being the stomach probably with some accessory organ. The mouth is surrounded with a variable number of long straight tentacula or arms, fringed on both of their lateral margins with cilia. When the arms are expanded, the cilia are thrown into rapid motion, which has the appearance of undulations proceeding along the fringes, upwards on one side of the arm or from its root to the point, and downwards on the other. While the cilia are thus moved, they produce currents in the water, as described in the Fresh-water Polype, and here also the currents in all probability serve for respiration and the prehension of food. Besides these motions in the water in the neighbourhood of the tentacula, a revolving motion of particles is observed within the body: small particles of extraneous matter which enter the throat are moved round within it; and the contents of the stomach and rectum undergo a very singular revolving motion round the axis of the cavity. These internal motions, Dr. Grant conjectured, might be owing to internal cilia; and I have been able to satisfy myself of the actual existence of such internal cilia, by means of a Wollaston's doublet of one-thirtyfifth of an inch focus; they are very evident in the throat; in the stomach they are most distinct in the part adjoining the rectum (indicated by *d* in the figure), and they are clearly to be seen on the whole internal surface of the rectum (*b*).

Fig. 292.

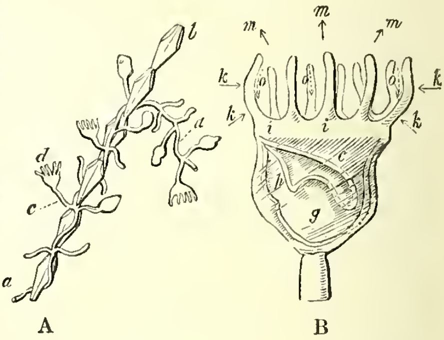


Polype of a Flustra in its cell.

* Vaucher, Bull. de la Soc. Philom. An xii.; Raspail, Mém. de la Soc. d'Hist. Nat. de Paris, for 1827; Meyen über Polypen, Isis 1828, p. 1225.

I have nowhere more clearly seen the above-mentioned phenomena than in a zoophyte, whose polype, though differing somewhat from the first form, may yet be referred to it. This zoophyte (*fig.* 293, A, B) has a creeping stem

Fig. 293.

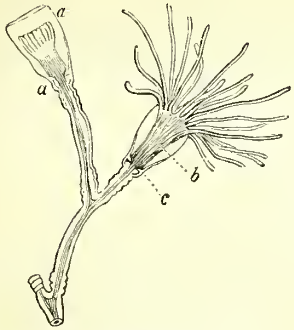


(*a*, *a*), which adheres to shells, or twines round the stems and branches of other zoophytes, (as *b* in the figure); the polypes are supported on soft pliable fleshy stalks (*c*), which the creature moves from time to time; their body (*d*, and B more magnified) is bell-shaped and consists of a transparent brownish skin or envelope containing the mouth and throat (*e*), the stomach (*g*), and rectum (*h*). The mouth, or expanded aperture of the animal, is surrounded by a prominent lip or border (*i*, *i*), to which the arms are attached. Cilia are distinctly visible on the arms, and within the mouth and stomach; they are moved very briskly, and small extraneous particles indicating currents in the water are hurried onwards towards the arms, as pointed out by the arrows at *k*, *k*; many of these particles descend along the inner side of the arms to their base, as shown by the dotted arrows *o*, *o*, *o*, and thence into the cavity of the mouth, from which, after being moved about for some time, the greater number are thrown out. It would seem that the particles of food or other solid matter, after being conveyed to the inside of the arms, take then a different course from the stream of water. The latter passes inwards between the arms, and issues from the middle of the irregular circle which they form (as at *m*, *m*), carrying with it such solid matters as are not arrested on the arms; but the bodies which enter the mouth are slowly carried along the inside of the arms (as at *o*, *o*), and in close contact with them till they reach their base. The motions of the contents of the stomach and its cilia appeared as in the Flustræ. I could perceive none in the rectum. Mr. Lister has described the same phenomena in a zoophyte closely resembling this one in the structure of the polypi, but differing in the character of the stem.*

* Phil. Trans. for 1834, p. 385.

In the second form (*fig.* 294) the stem and

Fig. 294.

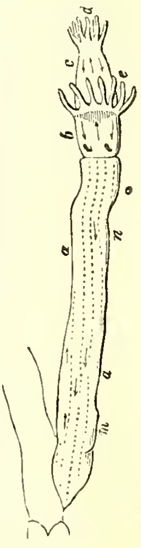


Campanularia.

branches are formed externally of a tough (generally horny) substance, and within this of a transparent soft tissue, which is tubular and contains a granular matter. The polypi resemble hydræ; each is lodged in a horny cell (*a*, *a*), from which it partially protrudes itself; one orifice surrounded with tentacula serves both for receiving aliment and discharging fæces; this leads to a stomach (*b*), which communicates through an opening (*c*) at the bottom of the cell with the interior of the tubular stem and branches, the attached part or base of the polype being continuous with the soft internal tube, of which the polypes might be regarded as a prolongation. In this form of polype, which exists in most true species of Sertularia, Campanularia, and Plumularia, and in allied genera, the tentacula or arms are destitute of cilia and incapable of giving an impulsion to the water. But a very remarkable motion has been observed by Cavolini* and Mr. Lister† in the granular matter contained in the stem and branches. Although this motion has not been traced to the agency of cilia, yet as it is connected with our subject, I shall briefly notice it here. When the stem and branches of the above-named zoophytes are examined with a high magnifying power, a current of granular particles is seen running along the axis of the tube. The current, which is compared to the running of sand in a sand-glass, after continuing one or two minutes in the same direction, changes and sets in the opposite one, in which it continues about as long, and again resumes the first, thus alternately flowing along the stem to the extremities of the branches, and back again. The change of direction is sometimes immediate, but at other times the particles are quiet for a while, or exhibit a confused whirling motion for a few seconds before the change takes place. Mr. Lister has discovered that the currents extend into the stomachs of the polypi, in which and in the mouth a remarkable agitation of particles is perceptible. When these particles are allowed to escape from a cut branch, they exhibit, according to Mr. Lister, something very like spontaneous motion. The immediate cause of these currents is not apparent; it seems not to be muscular contraction of the tube; perhaps, like the agitation within the stomach, they may be owing to internal cilia. As to their use Mr. Lister supposes the circulating matter "to be a great agent in absorption, and to perform a prominent part in the obscure processes of growth; and its flow into the stomach of the polypi seems to indicate that in this very simple family (the Sertulariæ) it acts also as a solvent of the food."—Page 77. Perhaps the polypi of the Pennatula and Virgularia should be referred to this head. In these Dr. Grant* discovered a constant vibratory motion within the mouth, apparently produced by cilia placed round the entrance of that passage, and he saw minute particles occasionally propelled from the mouth. Their tentacula, as in the zoophytes last referred to, did not excite currents.

The third form of polype is found in Tubularia. *Fig.* 295 represents a magnified view of a common species, the Tubularia indivisa. There is a transparent horny tube (*a*, *a*), containing a soft matter, which at the extremity of the tube is continuous with the stomach (*b*) and the mouth (*c*). There are two rows of tentacula or arms, one (*d*) immediately surrounding the orifice of the mouth, the other (*e*) further back, between the mouth and stomach. The arms are destitute of cilia and excite no movement in the water; but Mr. Lister† has discovered a remarkable motion of particles within the tube, which has some resemblance to the circulation of globules observed in plants of the genus *Chara*. These particles moved in a current within the tube, the general course of the stream being parallel to the slightly spiral lines of spots on the tube, and in the directions marked by the arrows. On the greater part of the side first viewed (the one represented) it set as from the polypus; but on the other side the flow was towards the polypus, each current thus occupying half the circumference. The tube had a granulated appearance between the lines of spots, and beneath this the particles ran. Their course was even and uniform without any starting or dancing motion, such as is observed in the Sertulariæ. At the nodous parts of the

Fig. 295.



Tubularia indivisa.

* Memorie per servire alla storia de' Polypi Marini, p. 121 and 197; p. 56 and 91 of the German Translation.

† Phil. trans. 1834, p. 369.

* Edin. Phil. Journ.

† Phil. Trans. 1834, p. 366.

tube (m, n) were slight vortices in the current, and at o near the end of the tube it came over from the opposite side. Two currents were continually going on in the mouth and the stomach, one always flowing down the sides in the direction e, e, and the opposite one in the axis. Neither the cause of these currents nor their use has been ascertained.

Such are the phenomena of the ciliary and other apparently allied motions in the Marine Polypi.

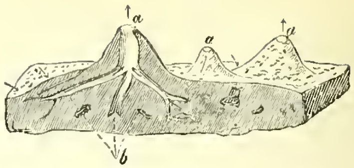
Spallanzani seems to have first noticed them; he observed the currents produced by the Flustræ, but erroneously attributed them to the agitation of the arms, the cilia on which he had not perceived. Dr. Fleming* described the current along the tentacula in the Valkeria cuscuta (a genus which he has separated from the Sertulariæ, among which it was previously included,) and distinguished the cilia with their undulatory motion. Dr. Grant† discovered the cilia on the arms of the Flustræ and described their undulatory motion, to which he ascribed the motion in the water. He also pointed out the revolving motion of particles within the mouth, stomach, and rectum, and conjectured that it was owing to the action of internal cilia, which conjecture I have been able to verify. Dr. Grant also discovered the vibratory and probably ciliary motion within the mouth of the polype of the Pennatulæ. Loefling‡ first observed the agitation of granular matter within the stem and branches of the Sertulariæ. Cavolini afterwards more correctly described this as a current of fluid holding granules in suspension, running first in one direction and then in the other. Lastly, Mr. Lister observed anew these internal currents of the Sertulariæ, described them more minutely, and showed that they extended into the stomach of the polypes. Mr. Lister has also described the phenomena in the Flustræ previously observed by Dr. Grant. He discovered the currents within the stem of the Tubularia, which, as far as I know, had not been previously noticed.

c. *Sponges.*—In the various species of sponges, water, the element in which they live and grow, passes in currents through pores and canals in their substance, in a continuous manner, entering at one place and issuing at another. This phenomenon has not been directly traced to the agency of cilia; it comes nevertheless to be considered here, as such an agency is highly probable, and at least the motion of the water is not owing to any contraction of the canals in which it flows, but is obviously caused by some other kind of impulsion communicated to it by the surface along which it passes.

In a common sponge we see a number of pretty large orifices on the surface, each opening on the summit of a conical eminence or papilla (*fig.* 296, *a*). These openings are named

* Mem. of Wern. Soc. fol. p. v. p. 488.
† On the Structure and Nature of Flustræ. Ed. New Phil. Journal, vol. iii. 1827.
‡ Schwedische Abhandlungen, 1752, p. 121.

Fig. 296.



Sponge.

by Dr. Grant the "fæcal orifices." Innumerable small *pores* occupy the rest of the surface, and give to it its peculiar character. These pores penetrate to a certain depth, and lead into canals (b), which, uniting together and gradually growing larger, terminate in wide tubes, which open at the fæcal orifices. The pores, excretory canals, and fæcal orifices thus form continuous passages through the sponge. In the fresh state they are lined throughout with a smooth gelatinous coating.

When a living sponge is examined attentively in its native element, the water is perceived entering at the pores and issuing from the fæcal orifices, its course being indicated by the motion of any floating particles that may be present. The issuing currents are stronger than the entering, and are rendered conspicuous by excrementitious matters or sometimes ova, conveyed out at the fæcal orifices.

When sections of the sponge, including a greater or less extent of the internal canals, are placed in water, the fluid, according to Dr. Grant's observations, is still evidently moved along the internal surface of the portions of canals, although their continuity with the rest is destroyed. Dr. Grant could not detect cilia either in these canals or the pores which lead to them, but he discovered these organs on the ova of the sponge, which thereby execute remarkable spontaneous motions, and he is inclined to attribute the currents in the adult sponge also to cilia, which he conceives may probably exist, though, from their smallness, he has not been able to perceive them. At any rate he has shewn by most satisfactory observations, that the current cannot be ascribed to contractions in the canal, for in none of his numerous experiments instituted for the purpose, could he discover any sign of irritability, at least any sign of contraction of the tissue of the sponge on the application of stimuli.

Naturalists even of the earliest times, whose attention was directed to the phenomena exhibited by the living sponge, have remarked that water entered and passed out from its porous substance, but the true course of the fluid seems to have been unknown, it having been erroneously supposed to enter and issue by the same orifices. Dr. Grant,* to whose labours we owe most of the correct information obtained respecting the structure and functions of the sponge, demonstrated that the current is continuous, and flows always in one direction as above described, and proved that the motion

* Edin. Phil. Journal, vols. xiii. xiv. Edin. New Phil. Journal, vols. i. and ii.

of the water was not produced by contraction and dilatation of the tissue of the sponge, which he showed to be destitute of irritability. Dutrochet had made observations on the same subject, which were published subsequently* to those of Dr. Grant, and not anteriorly as he supposes; he perceived the constant direction of the current, and ascribed the phenomenon to *endosmosis* and *exosmosis*.

3. *Ciliary motion of the ova of Polypi and Sponges*.—The ova or gemmules of several of these zoophytes execute independent movements, and produce currents in the surrounding water. This singular fact was, it appears, first noticed by Mr. Ellis in 1755,† in examining a species of Sertularia, the Campanularia dichotoma; but he described the ova or embryos which he had seen in motion, as young polypi, already somewhat advanced in their formation. Cavolini,‡ in 1784 and 1785, observed the same phenomenon in the ova of the Gorgonia and Madrepore, and investigated it more fully. He saw the egg-shaped gemmules or ova, on quitting the parent, rise to the surface, and swim with their large end forwards, in a horizontal direction, till they fixed themselves on some spot where they were developed. Dr. Grant,§ in 1825, discovered similar motions in the ova of the sponge, and detected the moving cilia. The cilia covered the whole surface of the ovum, except the posterior tapering extremity, and in its motions the large end of the ovum was always directed forwards. When an ovum fixed itself, its cilia still continued to play, by which a current along its surface was kept up for some time. Dr. Grant also investigated the movements of the ova of the Campanularia, previously seen by Ellis, and of the Plumularia falcata. The ova of both these zoophytes are contained within transparent capsules, two or more being in each capsule, surrounded by a clear fluid. Dr. Grant distinctly perceived cilia vibrating on the surface of the ova, and causing, while within the capsule, an eddying motion of the surrounding fluid, but propelling the ova through the water when extracted from their capsule, as in the sponge. The ciliary motion has also been found in the ova of fresh-water polypi, having been discovered by Meyen‖ in those of the Alcyonella stagnorum, which is probably the same with, or at least nearly allied to the Bell-flower Polype.

By means of the remarkable provision here described, the ova of these fixed zoophytes are disseminated, and conveyed to situations suitable to become the abode of the future individuals. The same provision undoubtedly serves also to move the water along their surface for the purpose of respiration. It exists, as will be afterwards shown, in the ova of many other animals.

4. *Acalephæ*.—Many species of Medusæ are furnished with cilia, or at least with moving organs bearing a close resemblance to the cilia of other animals, though in the Medusæ they present several peculiarities. The cilia are found in all the Medusæ belonging to the order *Ciliograda* of Blainville, or *Ctenophora* of Eschscholz, of which the genus Beroe is a good example. Eschscholz* describes them as small pectinated or comb-like organs, ranged in longitudinal rows or stripes on the external surface of the body, with their flat surfaces in apposition. Each comb-like organ consists of many small, flattened, pointed filaments, united together by a common base, the points being directed towards the posterior extremity of the body. They are moved like fins, being slowly raised and suddenly struck back, by which means the body is carried through the water. In the Beroë and others of similar form, the cilia point towards the closed extremity of the body, so that the opposite or open end is carried forward. The animal seems to have the power of moving more or fewer of these organs as it may incline, by which means other motions besides direct progression are performed. The cilia, when separated from the body with a piece of skin, continue to move briskly for some time. A longitudinal vessel runs under each row of cilia, communicating with the rest of the vascular system, and containing a fluid, in which yellowish particles are suspended. Eschscholz regards these vessels as arteries, and considers the cilia as respiratory as well as locomotive organs. Dr. Grant, in describing the cilia of the Beroë pileus,† represents the parallel filaments of which the comb-like organs consist, as united together by a membrane as far as their points, like the rays in the fin of a fish.

Schweigger compares the vessels which run underneath the rows of cilia, to the canals communicating with the tubular feet of the Sea-urchin and Asterias; and Dr. Grant seems also inclined to ascribe the motion of the cilia, whose filaments he conceives to be tubular, to their being alternately filled and emptied of fluid derived from the longitudinal vessel, like the tubular feet of the Echinodermata. This view of their mode of action, however, is scarcely reconcilable with the observed phenomena, as will be afterwards shown in considering the structure of the cilia in general. Audouin believed that in the Idya, a genus nearly allied to the Beroë, the fluid of the longitudinal vessel, which he supposes to be water, is sent into the cilia; he therefore regarded them as respiratory organs. If the vessel under the cilia in this case, as in the Beroë, communicate with the rest of the vascular system, and its contained fluid be regarded as blood, then the cilia of the Idya, which, according to Audouin, are permeated by the fluid, would bear a certain analogy to the gills of fishes.

* L'agent immediat du mouvement vital devoilé, 1826, p. 179, and Annales des Sciences Naturelles, 1828, tom. xv. p. 205.

† Hist. Nat. des Corallines, p. 116.

‡ Memorie per servire alla storia de' Polypi Marini, Nap. 1785, p. 8, p. 48 of German translation.

§ Edin. New Phil. Journal, vol. i. p. 150.

‖ Isis, 1828, p. 1225, sqq. Isis, 1830, p. 186.

* System der Acalephen, p. 3.

† Zoological Trans. vol. i. p. 9.

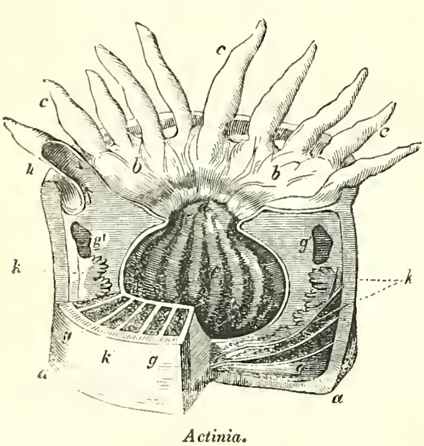
Cilia appear also to exist in other tribes of Medusæ besides the Ciliograda, but they differ in form and situation from those described, and have not been investigated with equal accuracy.

In Rhizostoma there are certain membranous appendages attached to the arms or tentacula, and bearing on their free edge a fringe of short filaments which are constantly in motion, and continue so for some time after the arm or portion of membrane supporting them is detached from the body. These filaments are described and figured by Eysenhardt,* who regards them as organs of generation; they are probably of the nature of cilia. Similar filamentary organs seem also to exist within the body in some Medusæ. (See ACALEPHÆ, p. 48.)

5. *Actiniæ.*—In a paper published on the present subject in 1830,† I mentioned that I had found the ciliary motion in the Actinia or Sea-anemony, but gave no description of it. I have since re-examined various species of Actiniæ with this view, and shall now describe the appearances; but to make the description intelligible, it may not be improper to remind the reader of some points in the anatomy of these animals which require to be kept in view.

The body of the Actinia, of which *fig.* 297

Fig. 297.



Actinia.

is a plan, consists entirely of a soft but tough substance, exceedingly contractile and irritable. It is usually cylindrical in shape, one end, (a, a,) named the base or foot, serving to fix the animal by adhering to rocks or other objects; the other extremity is named the disc, one-half of which is seen at b, b, the other half being removed by a section; it is surrounded at its circumference by the arms or tentacula (c, c,) in concentric rows, and in its centre is the mouth (d), or opening of the stomach, which serves both for the entrance of food and discharge of undigested remains. The stomach (e) is plaited longitudinally on its inside; vertical membranous partitions (g, g, g', g',) pass from its outer surface to the inside of the parietes of the body, and to the base, dividing the intermediate space into numerous compartments or cells, which communicate with each other by openings, as at g', g', and also open into the tentacula, as at h. The latter are conical muscular tubes, communicating at their base with the cells, and opening at their point by a small orifice, surrounded by a sphincter muscle. The cells seem also to communicate with the cavity of the stomach, and, according to Rapp,* they open in some species by small orifices on the surface of the body. The cells and tentacula contain sea-water, with which the animal can distend the whole body or any particular part of it. The protrusion of the tentacula, as is well known, is effected by their distension with water. The stomach also is often partially everted and protruded from the mouth by an accumulation of water behind it. It has not, so far as I know, been clearly shewn by which of the communicating orifices the water enters. Though I took considerable pains, I have not been able satisfactorily to ascertain this point; I may remark, however, that I have repeatedly noticed water entering at the mouth.

The ovaries and oviducts (k, k,) are lodged in the cells, and are consequently bathed in water; of these it is unnecessary here to say more than that one part of them consists of a waving membranous fold like a mesentery, attached by one edge to the sides of the cell, and at its free border supporting the oviduct, which resembles a white opaque chord, terminating, after numerous serpentine windings, in the stomach.

In regard to the ciliary motion in the Actiniæ, I am led from my observations to conclude that it exists to a greater extent in some species than in others. In all cases I have found it on the surface of the oviducts and their supporting membranes, which is covered with cilia of very minute size; also on the internal surface of the stomach, which has similar cilia, and there the currents follow the direction of the folds of the membrane. In one small but full-grown species I found currents commencing near the centre of the disc, and proceeding outwards in a radiating manner to its circumference, whence they continued along the arms as far as the points. On examining this species, which was semitransparent, by transmitted light, I distinctly perceived moving particles in the water contained within the tentacula and behind the protruded stomach.† The motion of these particles obviously indicated a current in the water along the surfaces containing it, which current, like that on the oviducts, it may be inferred was produced by cilia, for it went on while there was no perceptible contraction taking place in any part of the animal. The particles indicating the currents

* Nova Acta Acad. Cæs. Leop. vol. x. p. 404.
† Edin. Med. and Surg. Journal, vol. xxxiv.

* Ueber die Polypen und die Actinien. Weimar, 1829, p. 47.
† Some of these particles were no doubt the ova.

within the tentacula, were moved in two different directions, namely, from the base to the point, and from the point to the base; and (supposing the arm spread out horizontally,) the outward current was along the under part of the tube, and the returning one along the upper: (see *h*.) I also observed these internal currents of the tentacula in a young specimen of Actinia senilis, which seemed to have been very recently discharged from the parent; in it also there were radiating currents on the disc, but they stopped at the base of the tentacula. Thus the external currents on the disc and tentacula were found in one species, and they occur on the disc in some other species in the young state, but their occurrence in this situation is by no means general in adult Actiniæ.

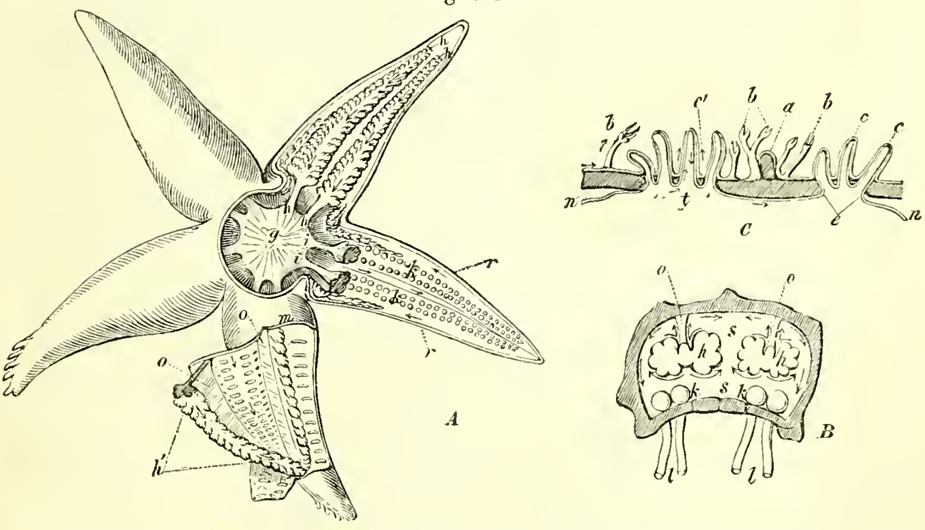
The phenomena described are in all probability connected with the processes of nutrition and respiration. They bear a striking analogy to those I have observed in the Echinodermata.

The ova of the Actiniæ were observed by Rathke to revolve round their axis, and occasionally to move straightforwards in the water. He could detect no cilia or other moving organs.*

6. *Echinodermata.*—The animals of this class in which I have observed the ciliary motion, are different species of the Sea-star *(Asterias)*, and the Sea-urchin *(Echinus)*. In proceeding to describe the phenomena in the Asterias, I must first take the liberty of explaining some points in the anatomy of that animal, referring the reader for other details to the proper sources, especially the monograph of Tiedemann.†

On the under surface of the Asterias, (I speak of the Asterias rubens in particular, *fig.* 298, A, B, C, as it is a large species and common on our shores,) we observe the mouth in the centre, and the tubular feet *(l, fig.* B) projecting in rows along the under part of the rays. Nearly the whole surface of the animal is beset with three kinds of eminences. First, hard calcareous processes, *(a, fig.* C,) placed like studs at some distance from each other. Secondly, claw-like processes (*b*, *b*); these singular organs are more thickly set; they consist of a solid stem of soft substance, bearing at the extremity a sort of pincers or forceps of hard calcareous matter, like the claw of a crab. They resemble analogous organs found on the Sea-urchin, only that the maxillæ or pincers in the latter consist of three pieces; they were named antennæ or feelers by Monro, but Müller regarded them as parasitical animals. The third sort of processes (*c*, *c*,) are named the respiratory tubes, and are the most important in regard to our present subject. They are short, conical, membranous tubes, communicating at their base with the internal cavity of the body, and perforated at their point by an orifice which can be very perfectly closed. Most of them are placed in groups or patches, and, corresponding with each group of tubes, the fibrous membrane forming the wall of the body presents on its inside a pit or shallow depression (*e*), perforated with holes, through which the tubes communicate with the general cavity. Like the tentacula of the Actiniæ, which they resemble in several other respects, they can be distended with water and elongated, or emptied, contracted, and shortened.

Fig. 298.



A, *Asterias viewed from above.* B, *Cross section of a Ray.* C, *Part of the section at m, fig.* A, *magnified.*

* Dorpater Jahrbüch. für Litt. Stat. und Kunst. Bd. i. Heft. i. p. 84—86, quoted by Purkinje and Valentin, p. 32. I have since seen the independent motion of the ova when extracted from the animal. It was shown to me by Mr. Graham Dalyell, who had long before observed it. The cilia could be distinctly perceived.

† Anatomie der Röhren Holothurie, &c. Landshut, 1816.

In the inside of the body the membranous stomach *(g)* occupies the middle part, and from it a pair of lobed cœca *(h, h,)* (and *i, i*, cut short) pass into each ray. Within the rays also we find inferiorly the rows of vesicles *(k, k)* which form part of the feet *(l, l)*, and the ovaries. All the rays communicate through the middle part, and the whole inside is lined by a transparent membrane *(n, n)*, which, like a sort of peritoneum, covers the stomach and cœca, attaches each of the cœca by a mesentery *(o, o)* to the roof of the ray, lines the fibrous parietes of the body, and is probably reflected over the vesicles of the feet and the ovaries. Each mesentery encloses a space *(o, fig.* B) between its sides, which opens into the general cavity at the root of the cœca. The lining membrane passes into the perforated pits *(e)*, by which the tubes *(c)* communicate with the cavity, and sends prolongations through the perforations into the tubes lining them to their points. The space *(s, s, fig.* B) lined by this membrane contains sea-water, which is generally described as entering and issuing by the respiratory tubes.*

I find the ciliary motion in four situations, namely, 1. on the external surface; 2. within the cavity of the body, or in the space *(s)* between its parietes and the viscera; 3. within the stomach and cœca; 4. within the feet. In all these situations moving cilia are visible with the microscope on the respective surfaces; they are every where comparatively small, in some parts excessively so. Though I have not traced them over the entire extent of each surface, I have no doubt they exist at every point where currents are produced.

1. On the external surface. The ciliary motion as indicated by the application of powdered charcoal, occurs over nearly its entire extent, but with different degrees of intensity. The strongest currents pass along the outer surface of the tubes from the base to the point, as at *c'*; they are also pretty strong on the claw-like processes *(b')* and intermediate skin; on the feet they are evident but less vigorous.

2. Within the body the currents take place on the lining membrane and its reflections. A longitudinal current runs along the roof, and another along the floor of each ray, forwards or towards its point: (see the arrows in *fig.* A.) These advancing currents are confined to the median line and its immediate vicinity; two retiring currents *(r, r,)* run backwards (one on each side) at the place where the sides join the floor of the ray. Two longitudinal currents also exist on each of the cœca, an advancing one *(h')* on the inferior surface, and a retiring one superiorly (*h, h, fig.* A) in the space *(o, fig.* B) inclosed within the mesentery, which, as already mentioned, opens into the general cavity. The longitudinal currents, except those within the mesentery, are, if for the sake of explanation we may so express it, connected by others which run vertically and transversely on the cœca and on the roof and sides of the cavity, (see the arrows in *fig.* B;) on the vesicles of the feet the course of these cross currents is varied by the curved surfaces. As the lining membrane of the cavity extends into the respiratory tubes, so currents exist within these likewise, as at *t, fig.* C. This is proved by injecting turbid fluid into the ray, when particles are seen moving within the tubes; and if a few of the tubes with a portion of the skin be cut off and placed under the microscope, the fluid which will still be retained by some of them may be seen to be in motion, the floating particles moving from the base to the point and back again, as in the arms of the Actiniæ.

3. The motion is very distinct on the inner surface of the stomach and cœca; the currents within the cœca follow the same direction as on their external surface, that is, an advancing current runs inferiorly from the root to the point and a returning one superiorly; and at the sides currents run upwards, following the ridges or folds of the internal membrane which result from the lobulated structure of the cœca.

4. The ciliary motion exists distinctly within the feet, though the cilia are very small; these became visible on viewing the edge of a folded portion with Wollaston's doublet of one-thirty-fifth of an inch focus.

The currents described, as far as I have been able to perceive, preserve always the same determinate direction. Even when portions of the ciliated surface are detached, the motion on them continues, and its direction is the same as before their separation.

As to the use of these motions, it is most probably connected chiefly with respiration; and if such be the case, it would show that in this animal a great extent and variety of parts are concerned in that function. The ciliary motion on the inner surface of the stomach and cœca is probably subservient also to the process of digestion. It is conceivable that by means of this provision the dissolved or digested food might be introduced into the cœca, and spread over their internal surface, there to be duly mixed with secreted fluids and subjected to the process of absorption; the returning current serving to bring back the residue, or to convey secreted fluids into the stomach. Or, considered as subservient to respiration, the ciliary motion, in diffusing the digested food over the internal surface of the cœca, may at the same time expose it to the respiratory influence of the water on their outside.

These phenomena in the Asterias seem not to have been previously noticed. Tiedemann,* it is true, had observed an eddying motion of the water in the vicinity of the respiratory tubes while the animal was slowly distending or emptying itself, but he conceived it to be nothing more than the commotion necessarily produced by the passage of the water through the tubes. There can be little doubt that the

* Without denying this mode of entrance, I may yet mention, that though I have often seen the animal slowly distending itself with water, and again partially emptying itself, I could never perceive the fluid entering or issuing at the orifices described.

* Anat. der Röhren Holothurie, etc. p. 40.

phenomenon he saw was caused by the ciliary motion on the external surface, though he was not aware of this.

Having entered into these details respecting the Asterias, I may describe more briefly the phenomena in the Sea-urchin, the more so as my opportunities of observing this animal have been less frequent.

The species submitted to examination was the common large Sea-urchin of our shores, Echinus esculentus, described by Monro.* Its body consists of a globular shell, containing the viscera. The mouth is placed underneath, the anus opposite on the upper surface. The tubular feet are disposed in vertical rows from the mouth to the anus, the intermediate part of the shell being covered with moveable spines, and the singular claw-like organs referred to in describing the Asterias. As in the Asterias, there are membranous respiratory tubes, but they are comparatively few in number, forming ten small bunches or groups, which are placed on the under surface not far from the mouth, and open internally in ten small perforated pits, like those of the Asterias; they are supposed by Tiedemann and others to be the channels by which the sea-water gets into the interior of the body, and fills the space between the inside of the shell and the contained viscera. The alimentary canal, commencing at the mouth, rises through the curious dental apparatus named Aristotle's lantern, turns in a waving manner twice round the inside of the shell, and terminates above at the anus; it is supported by a mesentery derived from a membrane which lines the cavity of the shell, and which is reflected over its contents like a peritoneum. Inside the shell we also find the ovaries and the rows of feet. The internal parts of the latter, instead of being round vesicles as in the Asterias, are broad laminæ enclosing vessels,† canals or branched cavities, which canals, like the vesicles of the Asterias, communicate on the one hand with the tubes of the feet, and on the other with a common vessel which runs along the middle of each double row of laminæ. The vessels or spaces within the laminæ are much branched; they form a plexus surrounded by a principal vessel at the border.

I have found the ciliary motion over nearly the whole surface of the cavity of the body and the contained parts, which surface, as mentioned already, is covered by a lining membrane or peritoneum. Two longitudinal currents run on the intestine in the same direction, viz. one along the line of attachment of the mesentery, the other at the opposite part of the tube. On the remaining circumference of the intestine the impulsion is directed obliquely towards the nearest longitudinal current. In regard to the laminæ of the feet, a current runs down the middle of each of the double rows, following the course of the longitudinal vessel there situated, the direction being from the anus towards the mouth. Lateral currents pass over the surface of the laminæ from their external to their internal border, where they join the middle current; they follow the irregular elevations on the surface of the laminæ occasioned by the canals or vessels in the latter; hence, when charcoal powder is applied, the particles follow winding paths in crossing from one edge of the laminæ to the other, and they are frequently caught in a hollow between two currents, and whirled about for some time before they resume their way. Currents were visible also on the reflections of the lining membranes which cover and pass between different parts of the lantern, and at the internal openings of the respiratory tubes. The cilia on the parts described are excessively small, but distinctly perceptible. The ciliary motion was not detected on the external surface of the body nor within the alimentary canal; but in regard to these parts the observations could scarcely be considered as conclusive; nor could I determine whether, as in the Asterias, the phenomenon occurs within the feet or within the spaces or vessels of their membranous laminæ, though from an observation of Carus, who states that he saw globules circulating within these laminæ, its existence in that situation is not improbable.*

This provision in the Echinus is probably, as in the analogous cases already described, chiefly subservient to respiration. Tiedemann, who ascribed a respiratory office to the water within the animal, expresses himself at a loss to conceive by what mechanism it can be made to enter and issue from a cavity with unyielding sides incapable of being expanded and contracted by muscular action; perhaps the provision here described may be adequate for this purpose. Since the above observations were made, a fact has been mentioned by Ehrenberg,† from which it appears that the ciliary motion exists on the external surface of the Echinus on the spines. The species observed by him was the Echinus sexatilis. The observations of Carus and Ehrenberg here referred to comprehend the only facts hitherto published on the ciliary motions of the Echinus which have come under my notice.

7. *Annelida.*—In proceeding to describe the ciliary motion in animals of this class, in several of which it occurs, it seems advisable to begin with the Aphrodita, as the phenomena in this animal present a remarkable analogy with those we have been considering in the Echinodermata.

A great part of the body of the *Aphrodita aculeata*, or Sea-mouse, (of which *fig.* 299, A, represents a cross section,) is occupied by the abdominal cavity, *(a, a, a.)* Along the superior wall of this cavity a row of cells *(b)* is placed on each side, which below open into the abdomen, but above, or exteriorly, project on the dorsal surface as oblong transverse eminences. Each alternate cell on the back bears a broad membranous scale *(c, c)*, and each of the intermediate ones a small indented process. On the back a covering of felt-like substance *(d)* is stretched from side to side like a roof over

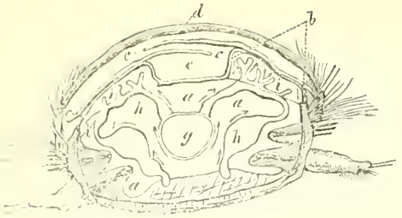
* Anatomy of Fishes, &c.

† Accurately described by Monro, l. c.

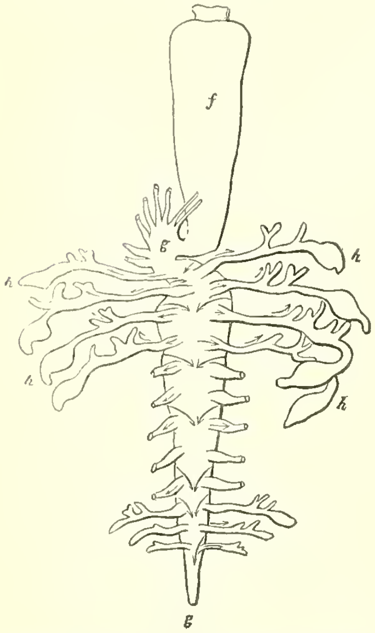
* Analecten zur Natur-wissenschaft, etc. Dresden, 1829, p. 152.

† Müller's Archiv. Band 1, p. 578.

Fig. 299.



A. *Cross section of the Aphrodita aculeata.*



B. *Alimentary canal and cœca, seen from above.*

the cells and scales, inclosing them in a space *(e)* to which the water has free access. Returning to the abdomen, we find the nearly straight alimentary canal, its anterior third *(f, fig.* B) forming the stomach, the remaining part or intestine *(g, fig.* A and B) being furnished on each side with a number of long cœca *(h)*, whose branched extremities *(i, i)* are in part lodged in the before-mentioned cells. The abdomen is lined with a delicate peritoneal membrane, which also lines the cells, and is reflected over the viscera.

In the living Aphrodita the water freely enters and issues from the space (*e*) beneath the felty membrane, passing over the external surface of the cells and their appendages. The flow of the water in this passage is produced, as I have repeatedly observed, by the elevation and depression of the scales, and on no part of the surface over which the fluid passes is the ciliary motion to be observed. But the water also enters the cavity of the abdomen, though it is doubtful by what orifices this takes place, for my endeavours to find those described by Treviranus* in the alternate intervals of the feet have never been successful. In whatever way it may happen, however, there can be no doubt of the fact that the water enters the abdomen, and consequently fills the dorsal cells and surrounds the intestine and its cœca, which last organs, according to Sir Everard Home and Treviranus, exercise a respiratory function, an opinion which derives additional probability in considering the phenomena of the ciliary motion to be here described. The ciliary motion exists in two situations, 1st, on the external surface of the intestine and cœca and the internal surface of the cells, which surfaces are in contact with the contained water; 2dly, within the intestine and cœca, or on their internal surface. The motion as usual persists for some time in detached parts, and the direction of the currents is constant. On the intestine the currents pass from the inferior surface round the sides to the upper part (as marked by the arrows). On the cœca the direction is outwards or towards the cells, and the motion is very distinct at their extremities. The direction on the inner surface of the cells was not completely made out, but it seemed to be chiefly downwards. Nor was the direction of the impulsion satisfactorily ascertained on the internal surface of the intestine and cœca, though of the existence of the phenomenon in that situation there could be no doubt.

From what has been stated, it appears then, first, that in the Aphrodita the water finds access to the outside of the cells, over which it is conveyed by the elevation and depression of the dorsal scales, and to the inside of the cells, over which, as well as over the external surface of the intestine and its cœcal appendages, it is moved by the action of cilia. In both situations the motion of the fluid is probably subservient to the respiratory function, and if it really be so, we must reckon the scales, the cells, the alimentary canal, and its appendages, as constituting the respiratory apparatus. Secondly, that the ciliary motion exists also on the internal surface of the intestine and cœca, where it is likely connected both with respiration and digestion. In all this we cannot overlook the analogy which subsists between the Aphrodita and Asterias. In both the water is conveyed, though by a different mechanism, over the external surface of the body; in both it enters the cavity containing the viscera; in both it is moved along the parietes of the cavity and surface of the viscera in a determinate direction by the agency of cilia; and, lastly, in both the ciliary motion occurs on the internal surface of the digestive organs.

I first observed the ciliary motions in the Aphrodita aculeata in 1830, at the same time with the late Mr. Cheek, who gave notice of the fact in the journal of which he was conductor;† but most of the observations on

* Zeitschrift für Physiologie, Band iii. p. 158.

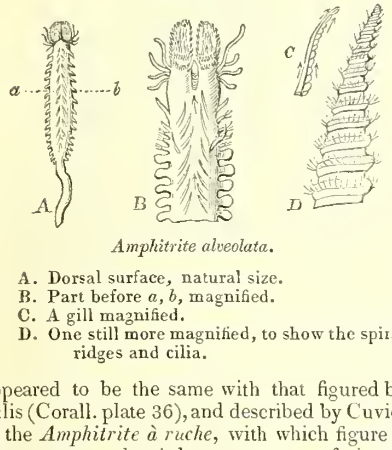
† Edin. Jour. of Nat. and Geog. Science, April, 1831, p. 246.

which the preceding account is founded, were made more recently. There is no mention of the existence of the phenomenon in the Aphrodita to be found in systematic works on comparative anatomy, nor in any of the special memoirs on that animal which I have had an opportunity of consulting.

The ciliary motion exists in several other animals belonging to the class Annelida. It is remarkably distinct, and easily observed, on the branchiæ or gills of the Serpula. These organs consist of two bunches of pinnated or feather-like processes, which the animal pushes forth from the calcareous tube in which it lives, and spreads out in a radiating form. The edges of the branchiæ, both of the stems and of the leaflets, are fringed with cilia, which exhibit their vibrating and undulating motions, and cause a constant current of water over the surface of the gills, serving here, no doubt, as in analogous instances, at least chiefly for respiration.

In a paper already referred to,* I mentioned having observed the phenomena in question in the Amphitrite. The animal meant was a common marine tubicolar worm (*fig.* 300), which

Fig. 300.



Amphitrite alveolata.

A. Dorsal surface, natural size.
B. Part before *a*, *b*, magnified.
C. A gill magnified.
D. One still more magnified, to show the spiral ridges and cilia.

appeared to be the same with that figured by Ellis (Corall. plate 36), and described by Cuvier as the *Amphitrite à ruche*, with which figure it agrees, except that it bears two rows of simple filaments on the back, which, for reasons that will appear, I was led to regard as gills. But if these are really gills, the animal must, it seems, be arranged with the Dorsibranchiata, probably as a Sabella. The currents in this worm proceed forwards along the back, between the rows of gills (as marked in *fig.* B), and along the gills themselves (see C), whose points are directed forwards. The conical filament of which each gill consists is marked on one side by ridges (see C, D), crossing it obliquely like segments of a spiral; and on these ridges as well as on the point of the gill the most conspicuous cilia are placed. The cilia are comparatively large and curved, their points being turned towards the summit of the gill, which figure they retain when their motion is stopped. The gills contain large bloodvessels, which when distended give them a bright red colour.

* Edin. Med. and Sur. Jour. vol. xxxiv.

The ciliary motion occurs also on what seem to be the branchiæ of another tubicolar worm, the name of which is unknown to me; the organs in question are placed at the anterior extremity of the animal, concealed by a profusion of long serpentine tentacula.

Lastly, Mr. Cheek* observed the ciliary motion in the Sandworm (*Arenicola piscatorum*). It was seen on the inner surface of the internal vesicles, which Sir Everard Home describes as livers. Nothing similar exists on the tufts of filaments which form the gills.†

8. *Mollusca.*—The ciliary motion prevails very extensively in this division of the animal kingdom. It seems to exist generally in the Gasteropodous and Acephalous Mollusca. There is some uncertainty as to its existence in the Cephalopoda; I have repeatedly sought for it in that class, but without success.

It occurs on the surface of the respiratory organs, and often on other surfaces over which the water has to pass in the act of respiration. It also exists within the alimentary canal, at least this has been ascertained in several species of Gasteropoda and Acephala, and may be presumed of the rest. Moreover, in some of the Gasteropoda, it is very manifest on the horns or feelers, which suggests the possibility of its aiding in these instances in the exercise of the sense of touch or smelling. In all cases the impulsion maintains a determinate direction, which continues the same in parts detached from the animal. In salt-water species, the action of the cilia and impulsion of the fluid, are instantly stopped by putting the parts into fresh water.

The ciliary motion also occurs in the embryo of the Mollusca within the egg, which phenomenon will be considered in the next section.

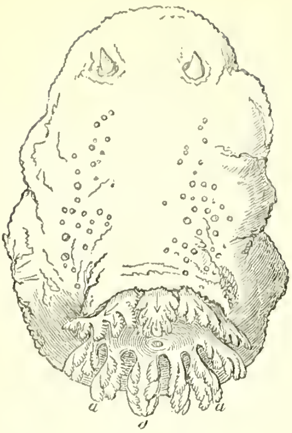
A. *Gasteropodous Mollusca.*—Of this class the phenomena have been observed by myself and others in the orders of *Nudibranchiata*, *Cyclobranchiata*, *Pectinibranchiata*, and the aquatic *Pulmonifera*, in one or more species of each.

a. Nudibranchiata.—In this order, in which the gills are entirely exposed, the currents can be very easily observed. The Doris, a species of which is represented in the adjoining figure (301), may serve as an example. The arborescent gills (*a*, *a*) are ranged in a circle round the anus, and their stems and branches are covered with cilia. Currents pass over their surface, the general direction being towards the points; small portions detached still excite currents in the same direction, and, if free, move through the water in the opposite one. I have examined three species of Doris, and

* Edin. Journ. of Nat. and Geog. Science, April, 1831, p. 245.

† The ciliary motion has also been observed in Planariæ, on the surface of the body, by Gruithuisen, (Salzb. Med. Chir. Zeit. 1818, vol. iv.) and by Purkinje and Valentin Gruithuisen also discovered it in the Nais proboscidea, in the posterior part of the intestine, (Nov. Act. Acad. Cæs. Leop. xi. p. 238.)

Fig. 301.

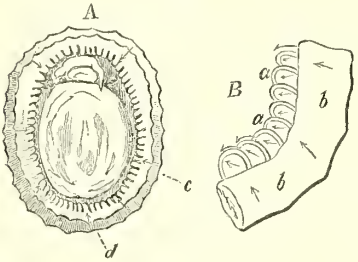


Doris.

in one of them, the D. cornuta, the ciliary motion was very strong on the club-shaped feelers; perhaps it may be the same in all. I also examined the Tritonia and Eolis belonging to this order, and found the ciliary motion in corresponding parts.

b. Cyclobranchiata.— In the Patella or Limpet (*fig.* 302, representing the under surface), the gills form a series of simple

Fig. 302.



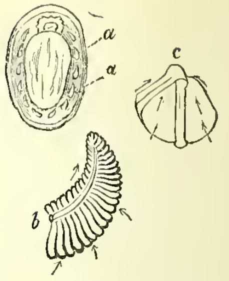
Patella.

B. Portion inclosed between the lines *c* and *d*, magnified to show *a, a*, the branchial laminæ, and *b, b*, the circular border of the mantle.

laminæ (*a, a*) attached within the circular border of the mantle (*b, b*). The currents pass inwards from the edge of the mantle to the gills, then over the surface and along the border of each branchial lamina, from its outer or lower to its inner or upper edge, as indicated in the figure by the arrows. In the Limpet the ciliary motion is also found on the inner surface of the alimentary canal.

In the Chiton or Oscabrion (*fig.* 303), the only other genus of this order, the gills are situated as in the Limpet, but are of a more complex structure. Each consists (at least in the species examined by me) of a triangular lamina, with a series of smaller laminæ set on each side of it, diminishing in size as they approach its point. The currents on each of the gills are directed towards its apex, and also pass between the secondary laminæ over their surface and along their edges: *a, a*, are the gills; *b* one of the gills magnified, showing its laminæ; *c* the same viewed endwise. The arrows mark the direetion of the currents.

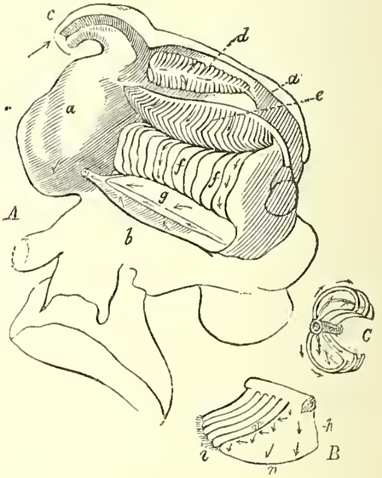
Fig. 303.



Chiton.

c. Pectinibranchiata.— The common Buccinum (*fig.* 304) may serve as an example of

Fig. 304.



Buccinum Undatum.

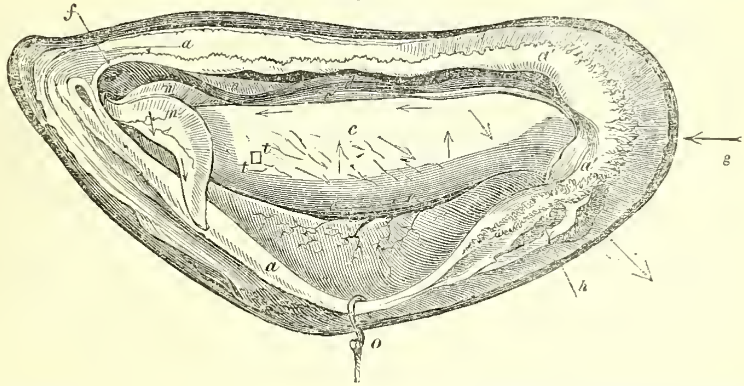
this order. The gills, as accurately described by Cuvier, are attached to the roof of a branchial cavity or recess formed between the mantle (*a, a*) and upper part of the body (*b*) in the last turn of the shell, and opening anteriorly by a broad slit. At the left end of the slit the edge of the mantle is prolonged in the form of a groove (*c*), which prolongation is called the syphon, and is lodged in a corresponding groove of the shell. On detaching the roof of the branchial cavity at the left side, and reflecting it (as represented in the figure), we find attached to it, first, the gills, consisting of a short double row (*d*) and a longer single row (*e*) of laminæ, the latter being larger; secondly, to the right of the gills, the so-named mucous laminæ (*f, f*); thirdly, still more to the right, the rectum (*g*).

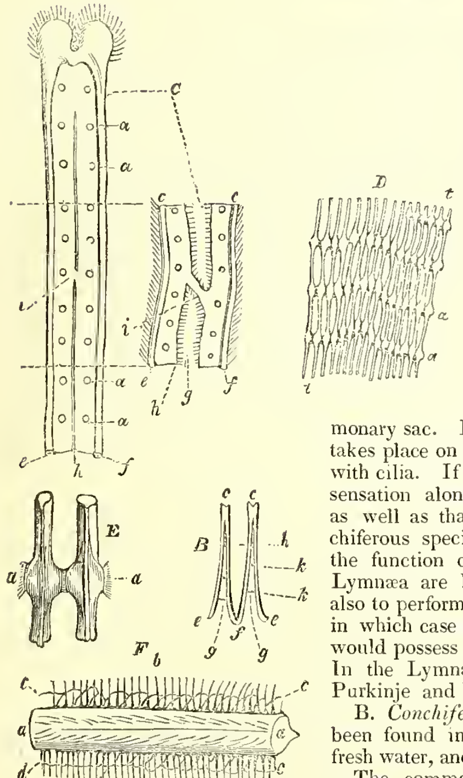
The water enters by the syphon, and issues at the right extremity of the branchial slit. The ciliary motion and currents take place on the gills, mucous laminæ, and reetum, and on the inner surface of the mantle, where it forms the roof of the branchial cavity. Their situation and direction are indicated in the figures by the arrows. B is an enlarged view of a few laminæ from the larger series, *h* the attached border, *i* point, *m* left, and *n* right border. Currents pass between these laminæ along the surface and border of each, as shewn in B; C is a magnified view of the laminæ of the smaller set, on which the direction of the currents is marked; the direction on other parts will be understood by referring to figure A.

The ciliary motion is very manifest within the alimentary canal, in the gullet, stomach, and intestine; the direction of impulsion is from the mouth towards the anus.

The ciliary motion has been observed by myself and others in the Paludina vivipara, a fresh-water snail belonging to this order,

Fig. 305. A





Mytilus Edulis.

F. Portion of a bar of the gill, with the cilia, highly magnified.

in which also Purkinje and Valentin state that they observed it within the alimentary canal; and Gruithuisen* has described the phenomenon as seen on the branchiæ of another fresh-water snail, which he names Valvata branchiata. He saw moving cilia, which caused an incessant agitation in the water; but he does not state whether the motion followed any constant direction, although we may infer that this was the case. He rightly attributed to these motions a respiratory function, but seems not to have observed that similar phenomena existed in other Mollusca.

d. Pulmonifera. The ciliary motion is not confined to those Mollusca which breathe by gills, for it occurs also in the Lymnæa and Planorbis, which, though they live in water, breathe air by a pulmonary sac. In these instances the impulsion of the water takes place on the surface of the tentacula, which is covered with cilia. If these parts are to be regarded as organs of sensation alone, the ciliary motion observed upon them, as well as that which occurs on the tentacula of branchiferous species, must be considered as connected with the function of sensation; but the tentacula, which in the Lymnæa are broad vascular laminæ, might be conceived also to perform the office of accessory organs of respiration, in which case the pulmoniferous Mollusca here mentioned would possess organs both of aerial and aquatic respiration. In the Lymnæa the motion has also been observed by Purkinje and Valentin within the alimentary canal.

B. *Conchiferous Acephala.*—The motion in question has been found in several bivalve Mollusca, both of salt and fresh water, and there can be little doubt that it exists in all.

The common Sea-mussel (*fig.* 305) will serve as an example of the class. It will be recollected that the gills of this animal (*fig.* A, *c*, *c'*, *d*,) have the form of

* Nova Acta Acad. Cæs. Leop. x. p. 437.

leaves, there being two on each side inclosed between the lobes of the mantle (*a*, *a*, *a'*, *a''*). Between the gills are interposed what is called the foot (*f*) and the prominent part of the abdomen, which separates the two of the right side from those of the left. Each gill or leaf consists of two layers, which are made up of vessels set very close to one another (*fig.* D,) like the teeth of a comb, or like parallel bars, across the direction of the gill, and perpendicular to the great vascular trunks running along its base, with which they communicate. The two layers composing each gill are connected together at its edge, and by a few points of their contiguous surfaces. At the base only one layer is fixed, the other terminating at this part by a thick unattached border (*e*, *e*), under which a probe may be passed into the interior space between the two layers. This is further explained by *fig.* B, which represents a section of the two gills of one side cut parallel to the bars. The layers (*e c*, *f c*,) are united at the edge of the gill (*c*), but separated at the base, the one being fixed at *f*, the other ending by a free margin, *e*. *g*, *g*, is the space between the layers; it communicates with the excretory orifice (*h*, *fig.* A). *Fig.* C shews the upper part of the gill, (*c*, *h*, *fig.* B,) viewed similarly, but magnified eighteen diameters. Two bars, (*e c*, *f c*,) belonging to opposite layers, are seen; they are shaped somewhat like the blade of a knife, with a thick round external border (*e*), and a thin internal edge (*h*) opposed to the corresponding one of the other layer, with which it is connected at a few places by cross slips, *i*, *i*, *fig.* C, and *k*, *k*, *fig.* B, where they are longer, the space at this part being wider. *Fig.* D is a small portion of one of the layers, (*t*, *t*, *fig.* A,) magnified eighteen diameters. The bars are connected laterally with the adjacent ones of the same layer at short intervals, by round projections on their sides, (*a*, *a*, *a*, *a*, *in figs.* D, C, and E,) in which last they are still more magnified. Each of these projections adheres but slightly to the corresponding one of the collateral bar, and its surface is covered with small filaments resembling the cilia in the other parts, only their motion is very slow. Besides the gills, the mussel has four triangular laminæ (*m*, *m*, *n*, *fig.* A,) placed round the mouth, which probably serve for respiration; they have been named labial appendages, tentacula, or accessory gills.

When a live mussel is placed in a vessel of salt water, it is soon observed to open slightly the two valves of its shell, and at the same time a commotion is evident in the water in its vicinity. This is occasioned by the water entering at the posterior or large end of the animal into the space between the lobes of the mantle in which the gills are lodged, and issuing near the same place by a separate orifice in a continued stream, as represented by the arrows, (*g* and *h*, *fig.* A), *g* being the entering and *h* the issuing stream. The existence of this continuous current is well known, but the agency by which the water is set in motion appears not to have been, at least generally, understood. It can readily be shewn that here, as in the instances already described, the water receives its impulse from the ciliated surface of the gills and other parts over which it passes, and that it is carried along these surfaces in a determinate direction. The whole surface of the gills and labial appendages or accessory gills, the inner surface of the cloak, and the surface of some other parts produce this effect, and the combined action of the cilia over this extensive surface gives rise to the main current which enters and issues from the animal.

On removing one of the valves, turning down the cloak, as represented at *o*, and putting moistened charcoal powder on the surface of the gills, the finer part of the powder soon disappears, having penetrated through the interstices of the bars or vessels into the space between the two layers of the gill. On arriving there a part is often forced out again from under the border of the unattached layer at the base of the gill, but most of it is conveyed rapidly backwards between the two layers, and is carried out at the excretory orifice with the general current, its course being indicated by the dotted arrows in the figure. The coarser particles remain outside the gill, and are slowly carried to its edge, following the direction of the bars; they then advance along the edge of the gill towards the forepart of the animal, as shewn by the entire arrows. It thus appears that the water first passes in between the lobes of the mantle to the external surface o. the gills; it is then forced into the space inclosed between their layers, from whence it is driven out at the excretory orifice, to which the inclosed spaces of all the gills lead. As this process continues to go on after the shell and lobe of the mantle of one side are removed, it is evident that the motion of the water must be mainly produced by the cilia of the gills, to be immediately described. By their agency the fluid is forced into the space within the gills, and this operation taking place over the whole extent of the gills, must, by its concentrated effect, give rise to a powerful issuing stream at the excretory orifice, of which the entering stream seems to be a necessary result.

The cilia are found on the gills, the accessory gills, the inside of the mantle, and the foot. Only those on the gills require particular notice. Most of them are arranged along the sides of the vessels or bars (*a*, *a*, *fig.* F), composing the gills, in two sets, one nearer the surface consisting of longer and more opaque cilia, (*b*, *b*,) the other close to the first, but a little deeper, and consisting of somewhat shorter and nearly transparent cilia, (*c*, *c*.) Both sets are in constant motion, but of this it is difficult to convey a correct idea by description. The more opaque cilia, or those of the exterior range, appear and disappear by turns, as if they were continually changing from a horizontal to a vertical* direction and back again. The

* By vertical is here meant a direction perpendicular to the plane of the gills, which direction is vertical when the gills are spread out under the microscope.

motion of the other set consists in a succession of undulations, which proceed in a uniform manner along the sides of the bar from one end to the other. It might be very easily mistaken for the circulation of globules of a fluid within a canal, more especially as the course of the undulations is different on the two sides of the bar, being directed on one side towards the edge of the gill, and on the other towards the base. But besides that the undulations continue for some time in small pieces cut off from the gill, which is inconsistent with the progression of fluid in a canal, the cilia are easily distinguished when the undulatory motion becomes languid. When it has entirely ceased, they remain in contact with each other, so as to present the appearance of a membrane, (*d*, *d*, *fig*. F.) Besides the two rows of cilia just described on each side of the bars, others are placed in a less regular manner on their external and internal borders. The internal (*h*, *fig*. C) are exceedingly small; they extend upon the cross slips, (*i*, *fig*. C). Those on the external borders are very numerous and thick-set, and of considerable size, especially on the extremity of the bar at the edge of the gill (*c*, *fig*. C); their points are directed towards the edge of the gill. It is probably by the agency of these last-mentioned cilia that the particles of food or other foreign matter are conveyed along the surface of the gill to its edge, and then onwards to the mouth, while the others may serve principally to force the water through the interstices of the bars into the space inclosed between the layers, and from thence out at the excretory orifice.

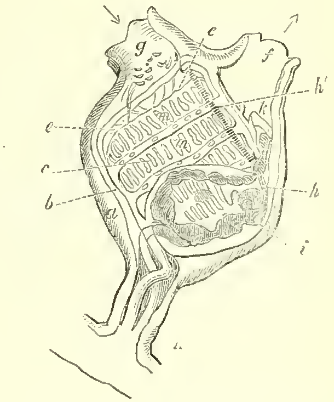
As in other instances, detached portions of the ciliated parts excite currents in the same direction as before their separation, or swim through the water in the opposite direction. It is very remarkable that when the parts are immersed in fresh water, the currents and motion of the cilia are almost instantaneously stopped.

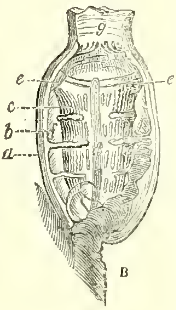
The ciliary motion is equally apparent on the respiratory organs of the Oyster, River-mussel, and other bivalve Mollusca which have been submitted to examination. Purkinje and Valentin pointed out its existence also in the alimentary canal of the River-mussel, which observation I have confirmed, and I have found the same to be true of the Sea-mussel. The impulsion appeared to me in both instances to be chiefly directed onwards, that is, towards the anus.

c. Tunicata (Ascidiæ).—In the paper previously referred to, I stated that I had not been able to perceive the ciliary motion in the Ascidia, but added that the observation seemed inconclusive, as the specimens examined had been some time out of the water. Since then I have seen the phenomena as distinctly in the Ascidiæ as in other Mollusca. The observations were made on a common species found adhering to rocks in the Frith of Forth at low water-mark, and as far as they go they agree with those lately made by Mr. Lister,* on a small aggregated species, the substance of which being nearly transparent enabled him to trace the currents more completely. For this reason it seems preferable to borrow his description.

The annexed figures (A and B) represent

Fig. 306.





one of these Ascidiæ on its peduncle, with the opening of the mouth (*g*) and the funnel (*f'*) in front. The outer covering is a tough coat (*a*), lined internally with a soft substance or mantle (*b*). A great part of the interior is occupied with the branchial sac (*c*), whose cavity terminates upwards at the oral opening, and is closed at the bottom. It is united to the envelope or to the mantle above and behind; the juncture (*e*, *e*,) beginning in front of the oral opening, extends backwards on each side of it, and then downwards along the middle of the back (*a'*, *fig*. A.) A vacant space (*f*, *f*,) is left between the sac and mantle at the sides and front, which ends in the opening of the funnel. The sac opens inferiorly into the œsophagus (*h*), which leads to the stomach (*i*), the intestine passing forwards and opening by the vent (*k*) into the funnel. On its sides and front the branchial sac is perforated by four rows of narrow vertical slits or spiracles (*m*, *m*), and through these the water, which flows constantly in at the mouth when its orifice is open, appears to be conveyed to the vacant space (*f*) between the sac and mantle, and it then escapes at the funnel. The sac seems extremely thin between the spiracles, but their edges are thickened, and they are lined with closely set cilia, which, by their motion, cause the current of water. When they are in full activity, the effect upon the eye is that of delicately toothed oval wheels, revolving continually in a direction ascending on

* Phil. Trans. 1834, p. 378.

the right and descending on the left of each oval, as viewed from without; but the cilia themselves are very much closer than the apparent teeth, and the illusion seems to be caused by a fanning motion given to them in regular and quick succession, which will produce the appearance of waves, and each wave answers here to a tooth.

Whatever little substances alive or inanimate the current of water brings, if not ejected as unsuitable, lodge somewhere on the surface of the branchial sac, along which each particle travels horizontally with a steady slow course to the front of the cavity, where it reaches a downward stream of similar materials *(h')*; and they proceed together, receiving accessions from both sides, and enter at last, at the bottom, the œsophagus *(h)*; this is a small flattened tube which carries them, without any effort of swallowing, towards the stomach.

Mr. Lister observed similar phenomena in a species of Polyclinum, another form of compound Ascidia, in which an excretory funnel is common to several individuals. Mr. Lister, p. 385, has adverted to the resemblance between the Ascidiæ and a zoophyte of a similar form to that here described at page 610. I may here point out an analogy on the other side, no less striking, between the Ascidiæ and bivalve Mollusca, in regard to the phenomena now under consideration. In both cases the water enters at one opening, and meeting with the surface of the membranous gills, passes through slits or interstices between their vessels into a space on the other side of the gill, which space terminates at another external opening, by which the water issues. In both cases also the margins of the slits in the gills are fringed with cilia which exhibit a waving motion, the waves proceeding in opposite directions on the two borders of the slit. Lastly, in both cases, while the water and finer particles of matter floating in it pass through the slits, the coarser matters are conveyed along the first surface of the gills towards the mouth. The difference lies chiefly in the nature and form of the external covering and the form of the gills in each; the membranous gills in the mussel being folded into double leaves on each side, and in the Ascidia being formed into a tubular sac; the space between the laminæ of each leaf in the mussel corresponding with the space *(f)* enclosed between the branchial sac and mantle in the Ascidia, both these spaces leading to the excretory orifice.

The remarkable appearances in the Mollusca described above could not wholly escape the notice of naturalists and microscopic observers. Thus we find Ant. de Heide,* a Dutch physician of the end of the seventeenth century, observing the appearance produced by the ciliary motion in the Sea-mussel; he names it "motus radiosus," or "tremulus." He found it in most parts of the animal, but in none more evident than the gills (cirri pectinati), in which it is most easily examined. "I call the motion radiant," says he, "because it proceeds from the whole surface of the eirrus (gill) almost in the same way as air-bubbles issue from crabstones or metals while undergoing solution; it may be called tremulous, because the parts affected by it vibrate. This motion goes on not only in the entire gill connected with the rest of the mussel, but even in the smallest pieces cut off from it, which by their radiant motion swim briskly through the sea-water."

* Anat. Mytuli, &c. 12mo. Amst. 1684

Leeuwenhoek likewise appears, from various passages in his writings,* to have perceived the moving cilia in the Oyster and Mussel; he noticed also the existence of the motion in detached portions. His observations, so far as they go, are correct; but he takes no notice of the currents in the water; nor does he seem to have perceived the relation of the phenomenon to the respiratory or other functions, or indeed to have formed any opinion regarding its physiological use.

Baker alludes to Leeuwenhoek's discoveries, and relates an appearance observed by himself in the Fresh-water Mussel, which must have been caused by the ciliary motion.† He states that "on snipping off a piece of the transparent membrane (gill), and viewing it with the microscope, the blood will be seen passing through numbers of veins and arteries, and if the extremity of the membrane be viewed, the true circulation or the return of the blood from the arteries through the veins will be shewn." Dr. Hales, in his Statical Essays, (vol. ii. p. 93,) plainly alludes to the same phenomena. Among more recent writers, Professor Ehrman of Berlin, in a memoir on the blood of the Mollusca, published in the Transactions of the Royal Academy of Sciences of Berlin for 1816-17,‡ has described an appearance noticed by him in Mya, Anodonta, the Oyster, and other Bivalves, which seems evidently to have been produced by the ciliary motion. He states that on viewing the inner side of the labial appendages, accessory gills, or tentacula of these Mollusca, while it was illuminated by a strong light falling in a particular direction, he perceived a very rapid and incessant motion along the transverse stripes or furrows observable on the surface of the part. The motion proceeded along each stripe like a series of oscillations. It continued for some time in portions cut off from the organ. He next observed that a number of round vesicular bodies escaped from the furrows or stripes at the part where they were cut, which bodies moved to and fro and as it were spontaneously in the water; and it seemed to him that in proportion as these bodies escaped, the oscillatory motion relaxed in intensity. From these facts he concluded that the motion apparent on the surface of the part was produced by the agitation of these vesicles or animated molecules within the furrows; that is, he supposed the furrows to be covered by a membrane to which an

* Epist. 83, in Opp. i. p. 463, 482. Anat. et Contemp. p. 52 in Opp. ii. Ibid. p. 27. Contin. Arcan. p. 17 in Opp. ii.

† Of Microscopes, &c. vol. i p. 128.

‡ P. 214, seq.

oscillatory motion was communicated by the agitation of the globules underneath it. He perceived the motion in question in no part but the labial appendages, and he imagined it to be connected with the male generative function, of which he therefore conceived the parts mentioned to be the organs. It is obvious that the appearance seen by Ehrman was the undulating motion of the cilia, which organs, however, he had not recognised. He makes no mention of currents, and consequently could not perceive the connexion of the phenomenon with respiration, which was also less likely to occur to him, as he supposed the motion to be confined to the appendages mentioned.

The observations of Ehrman led Treviranus to investigate the subject;* and he distinguished two different motions, the one a muscular contraction, the other the peculiar motion alluded to by Ehrman. The latter motion had the appearance of a trembling or flickering of innumerable points, and seemed at some places as if produced by a moving fluid, and at others by the agitation of oblong vibrating organs. It was peculiarly distinct alongside each of the bars of the gills and appendages. He farther perceived that the agitation on the surface of these parts caused an eddying motion in the water in which they lay, and also set in motion globules of blood which had escaped from the vessels. On breaking down the parts into small fragments, he found that each retained its power of motion, by which they moved in most manifold directions, the larger masses at the same time contracting and dilating themselves. From these observations Treviranus concludes that the bivalve Mollusca afford an example of a structure in which the integrant parts possess an independent vitality. Their independent vitality shews itself in the persistence of their automatic motion after solution of organic connexion with each other, and this motion is intermediate in its nature between the spontaneous movements of organic molecules in infusions, the male semen, &c. and the motion of muscular parts, which requires the integrity of the texture and the application of a stimulus. These reflections on the relation of the phenomenon to the general laws of organization are the sole inferences which he draws from his observations. He notices the motion of the water only as a concomitant and subordinate circumstance, not having been aware of its determinate direction, its relation to the respiratory process, or, in short, of its being the chief end and effect of the motion of the cilia.

The next researches on the subject are those of Huschke, narrated in a paper in the Isis for 1826.† Not having seen the original, we must content ourselves with a brief notice of them to be found in Burdach's Physiologie.‡ It is there stated that on detaching a portion of the gill of the Fresh-water Mussel (*Unio pictorum*), Huschke found that the water "moved upwards on one side, and then in an eddying manner back again."

* Vermischte Schriften, Band iii. p. 234.
† P. 623.
‡ Band iv. p. 434.

Raspail, in a memoir on a species of fresh-water polype, published in 1828,* pointed out the analogy between the phenomena exhibited by the gills of Mollusca and those observed in infusory animalcules and polypi.

Ciliary currents were now described by various other writers of eminence, but their causes were very commonly mistaken: among the number may be quoted Poli,† Delle Chiaje,‡ Carus,§ De Blainville,‖ and Unger.¶

Having observed currents produced in other instances by an impelling power inherent in the surfaces over which the fluid passed, I was myself led to suspect that the respiratory current in bivalve Mollusca was of the same kind, or that it was caused by an impulsion communicated to the water by the surface of the gills and other parts over which it was conveyed in its passage, without being aware of any similar view having been entertained by others. I then observed the determinate direction of the impulsion along the surface, together with the arrangement and action of the cilia. These observations were published at the time (1830) in a paper already mentioned,** in which also the respiratory currents of the bivalve Mollusca are considered as a particular example of a more generally prevailing phenomenon.

In a paper on the circulation of the blood, in Magendie's Journal for 1831,†† there are some remarks pertaining to the present subject, from which it appears that the author, M. Guillot, had observed the ciliary motion of the gills of the Sea-mussel and Oyster. He has, however, like Baker, mistaken the regular undulations of the cilia for the circulation of a fluid within vessels. He takes no notice of any motion or current excited in the water.

Carus,‡‡ in a memoir on the development of the River-mussel, states that he observed an undulatory or oscillatory motion of the gills, and that by this motion, which he conceives to be in the substance of the gill, the water is propelled, and the general respiratory current through the branchial cavity produced. It is obvious that what he calls an oscillation of the substance of the gill, and which he erroneously supposes has previously escaped attention, is merely the undulatory motion of the cilia.

The last researches on this subject which we have to notice are those of Purkinje and Valentin.§§ As above stated, they discovered the ciliary motion in the alimentary canal of the Mollusca, having found it in the Lymnæa, Paludina, and the Fresh-water mussel.

* Mémoires de la Soc. d'Hist. Nat. de Paris, tome iv. p. 131, seq. Chimie Organique, 1833, p. 246.
† Testacea utriusque Siciliæ, t. i. 51.
‡ Istituz. di Notom. e Fisiolog. comp. t. i. p. 278.
§ Lehrbuch der Zootomie.
‖ Malacologie, 157.
¶ Uber die Teichmuschel, p. 10.
** Edin. Med. and Surg. Journal, vol. xxxiv.
†† Tom. xi. p. 182.
‡‡ Nova Acta Acad. Cæs. Leop. xvi. p. 58, seq.
§§ Loc. cit.

Such is an outline of the observations hitherto made relative to the ciliary motion in the bivalve Mollusca. We may now shortly consider those which refer to the other classes of these animals.

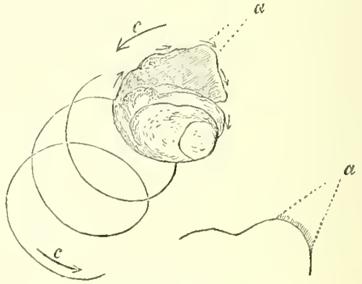
Dr. Fleming,* in describing the cilia in some species of Polypi, states that " analogous hairs" exist on the branchiæ of the Tritonia, which may probably be considered as forming part of the aerating organs. He also mentions, in another place,† that these branchiæ " readily fall off, and, as if independent, are capable of swimming about for a short time in the water, by means of minute hairs with which their surface is covered, and which move rapidly, pushing forwards the distal extremity." Gruithuisen, as formerly mentioned, observed the ciliary motion, and recognised its true nature in the Valvata branchiata, a species of fresh-water snail. Also Raspail,‡ having seen the phenomena produced by the gills of the Fresh-water Mussel, was led by analogy to discover the same in the Lymnæa and Paludina. Without being aware of these previous researches, I observed the ciliary motion in several different tribes of marine Mollusca, and shewed that it prevailed extensively among Mollusca generally. Mr. Lister, as has been already stated, has subsequently discovered that it exists in the Ascidia; and since then I have also found it in that animal, though in a different species.

9. *Of the ciliary motion of the embryo of Mollusca.*—The embryo of Mollusca exhibits, while within the egg, a peculiar rotatory motion which belongs to the class of phenomena we are here considering, and is referable to the same cause. This motion has been observed in the Gasteropodous and Bivalve Mollusca, and may perhaps be found in others.

Gasteropoda.—Swammerdam§ states that in examining the young of the viviparous water-snail, while they were yet inclosed in the membranes of the ovum, he observed the embryo turning round in the contained fluid with considerable rapidity, and, he adds, " in a very elegant manner." He again mentions the fact in another place.‖ Baker observed the same appearance in the ova of a fresh-water snail, which appears to have been the common Lymnæa. He says,¶ " when the eggs are about a week old, the embryo snail may be discerned in its true shape, turning itself very frequently within the fine fluid in which it lies." These brief notices of this remarkable fact by Swammerdam and Baker seem to have failed to excite the curiosity of succeeding naturalists, for there would appear to be no account of any subsequent researches on the subject till those of Stiebel published in 1815,** who seems not to have been aware that the fact had been previously noticed. Stiebel's observations were made on the ova of the Lymnæus stagnalis. They were followed by those of Hugi* in 1823, and Carus in 1824,† on the same species, to which Carus afterwards‡ (in 1827) added corresponding observations on the Paludina vivipara. About the same time (1827) Dr. Grant extended the inquiry to salt-water Gasteropoda, both naked and testaceous, and, as far as I know, was the first to point out the cilia, which are very conspicuous in salt-water species, as the agents which cause the rotation.

The eggs of the Lymnæus (or Lymnæa) are deposited in clusters, being imbedded in oblong masses of gelatinous matter that are found adhering to stones or water-plants. Each egg consists of an oval pellucid membrane, containing within it the yolk surrounded by a considerable quantity of limpid fluid. The yolk is at first round, without any obvious distinction of parts, but in the progress of development it changes its figure, and is gradually converted into the embryo, of which the shell and several principal organs can soon be distinguished. From the descriptions of the authors above mentioned, as well as from some observations made by myself, it appears that the embryo is at first motionless, but that as soon as the distinction can be perceived between the anterior or cephalic extremity and the rest of the animal, its rotatory motion commences. This invariably goes on in the manner indicated by the larger arrows (*c, c*) in the annexed figure, the head or anterior extremity

Fig. 307.



Embryo of Lymnæa.

continually receding. After a time the rotation is combined with a progressive motion, by which the embryo, while turning on its axis, moves onwards at the same time along the inside of the egg, performing a circuit like a planet in its orbit. The path described by a point on the surface is indicated by the spiral line in the figure.

Stiebel, as well as the earlier observers mentioned, is silent as to the cause of this curious phenomenon. Carus§ at first denominated it a primitive or cosmic motion, without clearly

* Mem. of Wern. Soc. of Edin. iv. p. 488.
† Philosophy of Zoology, v. ii. p. 470.
‡ Loc. cit.
§ Biblia Naturæ, p. 142.
‖ Op. cit. p. 179.
¶ Of Microscopes, &c. vol. ii. p. 325, 329.
** Diss. sist. Lymnæi stagnalis anatomen, Goetting, 1815, and Meckel's Deutsches Archiv für die Physiologie, Bd. i. p. 424. Bd. ii. p. 557.

* Isis, 1823, p. 213.
† Von den aüssern Lebensbedingungen der weiss-und kaltblütigen Thiere. Leipz. 1824.
‡ Nova Acta Acad. Cæs. Leop. vol. xiii. p. 763.
§ Von den aüss. Lebensb. p. 59.

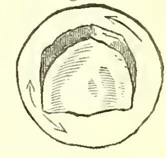
explaining what he meant by the term. Having subsequently discovered that a current existed in the fluid in an opposite direction to that followed by the embryo, he ascribed the motion to an attraction and repulsion exerted by the substance of the embryo on the surrounding fluid,* more especially at the region of the body where the respiratory organ was afterwards to be developed, and justly conceived that the chief purpose served by it was to renew the water on the respiring surface of the embryo. The attraction and repulsion again he supposed to be produced by an oscillatory motion which he perceived on the surface of the embryo. This oscillatory motion, although he describes it as taking place in the substance of the animal, seems to be nothing else than the usual undulatory play of moving cilia, such as has been already described in other instances,—indeed he himself compares it to the undulation on the arms of polypi. I have distinctly perceived the cilia, though they are very small, in the embryo of the small species of Lymnæa common in this country. It is the one represented in the figure, but considerably magnified. The current takes place along the whole of the surface indicated by the small arrows, which also mark its direction, being opposite to that in which the embryo moves. The cilia, though they probably exist over all this surface, were distinctly seen only on the part inclosed between the dotted lines at *a*; it required a doublet of one-thirty-fifth of an inch focus to make them visible.

Appearances similar to those described were discovered by Dr. Grant in the ova of Marine Gasteropoda. In examining the embryos of the Buccinum undatum and Purpura lapillus, which are inclosed in groups within transparent sacs, he was struck with a rapid and incessant motion of the fluid in the sac towards the fore part of the embryo, and he observed that this motion was produced by cilia placed around two funnel-shaped projections on the fore part of the young animal, which form the borders of a cavity in which he perceived a constant revolution of floating particles. He also observed these circles of cilia in the young of other testaceous Mollusca, as the Trochus, Nerita, &c. in which the embryo was seen revolving round its axis. He met with the same appearance in the naked Gasteropoda, as the Doris, Eolis, &c. The embryo of these revolves round its centre, and swims rapidly forward by means of its cilia, when it escapes from the ovum. My own observations on the ova of the Buccinum agree generally with those of Dr. Grant. The larger cilia are placed round the prominent border of a cavity on the fore part of the body, but the surface of the foot and other neighbouring parts is also ciliated, though the cilia are there much smaller. Dr. Grant assigns various uses to these motions; it seems not to have occurred to him that they were connected with respiration, although there can be little doubt that they are principally subservient to that function.

* Nova Acta, xiii. p. 771.

Acephala.—The rotation of the embryo of bivalves was discovered by Leeuwenhoek, and described by him in one of his epistles, dated October, 1695.* On examining the ova of a species of Fresh-water Mussel with the microscope, he observed the embryo turning slowly round within the egg, like a sphere revolving on its axis. This was at a time when the shell could be distinctly perceived on the young mussel; he had failed in discovering the phenomenon in some ova of the same species which he had examined at an earlier period of advancement.† He adds, that he was so much delighted with the spectacle of the young Mussels turning round within the egg, that he spent two hours along with his daughter and his draughtsman in contemplating it. Baster,‡ who wrote in 1762, seems to have observed an appearance of the same kind in the ova of the Oyster, if we may judge from a reference by Cavolini, for I have not been able to consult the original. More recently (1827) Sir E. Home and M. Bauer § perceived the motion in the embryo of the Fresh-water Mussel, as described by Leeuwenhoek, but erroneously attributed it to a small worm which pierces the egg and preys on the young mussel, and which, according to their view, by dragging on it pulls it round in the manner described. Lastly, Carus subjected the phenomenon to a more careful investigation, in the course of his researches on the development of the River Mussel.|| According to his observations the embryo, at the time the motion becomes perceptible, has acquired a flattened triangular shape (*fig.* 308), the two halves of the shell cover its two surfaces, and are united together by the hinge at the base of the triangle. When the ovum is placed under the microscope, the embryo is seen moving round in a horizontal direction, as indicated by the larger arrows, appearing as if it turned on the centre of the lowermost shell. When the embryo is extracted from the egg, a current is perceived in the water opposite that part where the current enters and issues in the adult animal, (as shown by the small arrow,) and Carus therefore attributes its rotatory motion to an attraction and repulsion exerted on the water by that part of the embryo, which is afterwards to form the respiratory organ. The attraction and repulsion of the water he supposes to be produced by an oscillatory motion observable in the substance of the animal at its surface, as in the embryo of the snail, which motion, as we have already seen, is in reality an undulatory movement of minute cilia. As in the snail also, he conceives the phenomenon to be connected with respiration. For an account of his

Fig. 308.



Embryo of Mussel.

* Ep. 95. Cont. Arc. Nat. 1697, p. 26, 27, in Op. tom. ii.

† Ibid. p. 20.

‡ Opuscula Subseciva, tom. ii. p. 146.

§ Phil. Trans. 1827, p. 39.

|| Nov. Acta, xvi. p. 27, sqq.

observations on the velocity and direction of the motion, and its supposed influence in determining the figure of the animal, I must refer to the paper itself.

The analogy of these motions of the embryo of the Mollusca with the phenomena exhibited by the ova of Infusoria, Polypi, Sponges, and Actiniæ, already described, scarcely requires to be pointed out. We shall afterwards see that it extends to the ova of Batrachian Reptiles.*

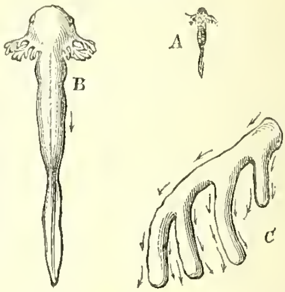
11. *Phenomena of the ciliary motion in the Vertebrata.*—The ciliary motion exists very extensively in vertebrated animals. Until lately it had been found only in the larvæ of Batrachian Reptiles, but Purkinje and Valentin† have recently made the important discovery that it exists also in adult Reptiles, Birds, and Mammiferous animals; and it seems to prevail generally throughout the three classes, having been found by these naturalists in all the numerous examples of each class examined by them in the course of their investigations. It has not been found in Fishes, though many species have been submitted to examination.‡

The parts of the body which exhibit the ciliary motion in the Vertebrata are, the lining membrane of the respiratory organs, and that of the generative organs in the female. Besides this general situation, it is found on the external gills and surface of the body in the larvæ of Batrachia, and on the surface of the embryo of these reptiles while contained within the ovum.

A. *Reptiles.*—The ciliary motion has been discovered in all the orders of Reptiles. It has been found in every species submitted to examination, and is therefore presumed to exist in all.

Batrachian Reptiles. 1*st. Larvæ and ova.*—The Batrachian Reptiles, while in the fœtal or larva state, breathe by means of gills or branchiæ, and it was on the gills of the young Salamander and Frog that the phenomenon under consideration was first discovered as existing in vertebrated animals. The gills of the young Salamander might in appearance be compared to feathers or pinnated leaves; there are three on either side, each consisting of a main stem bearing two rows of simple leaflets; they are wholly external, projecting backwards and outwards from the side of the neck. The tadpole of the Frog (*fig.* 309) has at first gills resem-

Fig. 309.



Larva of Frog.

bling those of the Salamander, but of a simpler form; they are also three on each side, but have each only five or six diverging branches. The gills of the Salamander, although not permanent, endure till the animal makes full use of its lungs, but the external gills of the Frog are of very short duration, being soon superseded by internal gills, more resembling those of a fish, with which the animal respires for the rest of the larva state.

By means of the microscope the blood may be seen circulating through the external gills of the Frog and Salamander; it passes outwards to their extremities by the branchial arteries, and returns in a contrary direction by the branchial veins. The water also is moved continually over these organs, for the purpose of respiration, in a constant and determinate direction, and this is effected by the peculiar impelling power we are here considering, viz. the ciliary motion on their surface.

Steinbuch,* a German naturalist already mentioned, while examining the circulation of the blood in the gills of the Salamander, observed that small bodies floating in the water were carried, as if by attraction, to the surface of the gill, and again repelled from it. He also found that portions detached from the gill moved themselves through the water, or if kept fixed, continued as before to attract and repel small objects in their vicinity. From these and similar facts he was led to conclude that the water was continually propelled over all parts of the gill, that the current thus produced served to renew the water in the process of respiration, that the power producing the propulsion resided in the gill, and was exercised independently of the will of the animal; and lastly, from the analogy of Infusoria and Polypi, in which currents are produced by cilia, he inferred that in this case also the water was probably impelled along the surface by the action of cilia, though he could not actually perceive any such organs. Steinbuch next examined the tadpole of the Frog, and found that its ex-

* In the preceding account of the ciliary motions in the *Invertebrata* no mention has been made of their existence in the class Crustacea: I think it necessary to state that I have examined this class, but without success; and since these pages have been put into the printer's hands I have re-examined the crab and lobster with the greatest care, all the respiratory and alimentary surfaces, the inner surface of bloodvessels, &c. with lenses of all powers, but without finding the phenomenon. I suspect the respiratory currents in Crustacea which are produced by the motion of the branchiæ themselves, or of the plates or oars with which many are provided in order to renew the water, have been confounded with the currents produced by cilia, more especially as many of the organs employed for the purpose in the *Crustacea* are fringed with long hairs; but I would scarcely reckon such motion as ciliary any more than those occasioned by the gill-covers of a fish.

† Müller's Archiv. 1834. Edinb. New Philos. Journal, xix. and Comm. Phys. de Phenomeno motus vibratorii continui. Wratislav. 1835, 4to.

‡ See note at p. 29.

* Analekten neuer Beobachtungen und Untersuchungen für die Naturkunde, Furth, 1802. p. 46, sqq.

ternal gills exhibited the same phenomena, but he could discover nothing of the kind on the internal gills.

Gruithuisen* observed in the tadpole of the Green Frog that so soon as the circulation of the blood began in any part of the gills, small objects were attracted and repelled from that spot, and that the same took place a few days later on the tail wherever vessels had been formed. He conceived that the motion of the water was for the purpose of exposing the blood to its influence, and compared it to the current produced by Infusoria by means of cilia. He does not say, however, that he had seen cilia in the tadpole.

Huschke† observed that the water in the vicinity of the gills of the young Salamander was thrown into a boiling-like motion, while it flowed steadily at other parts of the body.

Without being aware of these previous discoveries, I was led in 1830, by an accidental observation of my own, to go over nearly the same ground.‡ I had cut off one of the external gills of the tadpole of the Frog, and placed it with a drop of water under the microscope, with the view of measuring the size of the globules of blood that might flow from it, and was astonished to perceive that the globules, on escaping from the cut part of the gill, moved rapidly along its surface towards the points of the branches in a constant and uniform manner. On further inspection it soon became evident that the blood-globules were entirely passive in their motion, and that other light particles brought near the gills were moved in a similar manner; their motion being manifestly owing to a current produced in the water along the surface of the gill in a determinate direction. A conclusive proof of this was afforded by putting the gill which had been cut off, into a watch-glass with a larger quantity of water. It was then seen that when the gill happened to be fixed by any obstacle, small bodies in its vicinity were moved along it as before towards the points of the branches, but when unimpeded the gill itself advanced through the water in a direction contrary to that in which the particles were moved, the trunk being turned forward; the tendency to produce a current in one direction, thus causing the gill, now no longer fixed, to move in the opposite one. The current began at the root of the gill, and ran along the branches, at the points of which it did not continue its primitive direction, but turned off sideways, and immediately ceased. (See *fig.* 309, C).

I soon found that the gill was not the only part of the animal which excited motion in the water. Nearly the whole surface of the body produced the same effect. A general current commenced on the fore part of the head, proceeded along the back and belly and the two sides, to the tail, along which it continued to its extremity. It was not so strong as that on the gills, but agreed with it in other respects.

I continued for some time to observe the phenomenon in the larva of the Frog, in order to find out whether it underwent any alteration in the progress of the developement of that animal. It is known that after a time the external gills become covered by a fold of the skin, and inclosed in the same cavity with the internal gills, when they gradually shrink and at last disappear. On examining the animal while this change was taking place, and for some time after, it appeared that the external gills after their inclosure still retained their peculiar property, and continued to do so as long as any portion of them remained; the current on the body remained the same; on the tail it acquired a twofold direction diverging from the middle part or continuation of the vertebral column, obliquely upwards and downwards towards the upper and lower edge. As the animal advanced in growth, the currents gradually disappeared over the greater part of the surface, continuing longest at the posterior part of the body; at length, when the posterior extremities were so far advanced in growth that the thigh, leg, and toes could be discerned with a magnifying glass, which was the latest period of observation, the current existed only at the commencement of the tail, and on a small part of the body near the hind leg. The internal gills, though tried in various stages of development, did not exhibit the phenomenon.

I next sought for the same appearances in the larva of the Newt or Water Salamander, which was first examined a few days after its exclusion from the egg when its gills are very simple. At this period the surface of the animal produces currents agreeing in almost every circumstance with those which take place in the larva of the frog at a corresponding stage of its development. Particles of powder diffused in the water are carried along the surface of the body from before backwards; on the gills they are conveyed along each of the trunks from the root to the extremity. The gills also, when cut off, move through the water with the cut extremity forwards, in a direction contrary to the currents. I have since found nearly the same phenomena in the gills at a much later period.

It was evident that the purpose of these currents was to effect a renewal of the water on the respiratory surfaces; respiration in these animals probably being performed not only by means of the gills, but also by the general surface of the body.

It appeared that the power of impelling the water was wholly confined to the external surface of the animal; a portion of the skin being raised and detached, floating bodies were moved along its external surface only. Parts cut off from the animal continued to excite currents for several hours after their separation, and the smallest portion produced that effect. In these cases the current always moved in the same direction relatively to the surface of

* Salzburg. Medicinisch-Chirurgische Zeitung, 1819, ii. p. 447.

† Isis, 1826, p. 625, (cited in Burdach's Physiologie, from which I quote, not having seen the original.)

‡ Edinb. Med. and Surg. Journal, xxxiv.

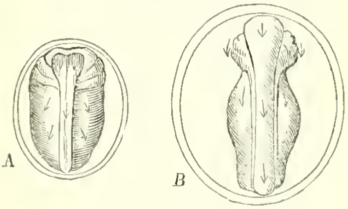
the detached parts, as it had done previous to their separation.

At the time of making these observations I had not been able to detect Cilia in these larvæ, although, from the analogy of the Invertebrata, I was led carefully to look for them. Since then I have succeeded in perceiving them with the aid of Wollaston's doublet of one-thirtyfifth of an inch focus, especially when a portion of the gill is compressed under a plate of mica. They are to be distinguished chiefly by their waving motion, which is so characteristic as to remove all doubt of their existence; though here, as in other instances in which they are very minute, it is not always possible to demonstrate their existence by actual observation on every spot of the surface.

Ova of the Batrachia.—In the course of the above-mentioned observations, I was led to enquire whether the phenomena in question appeared at a still earlier stage. With this view I examined the ova of the Newt, which for a considerable time may be procured in all degrees of advancement, and found that the ciliary motion presented itself in the embryo a considerable time before its exclusion from the egg. Since then I have observed the same with regard to the embryo of the Frog.

In both cases the embryo is formed from the yolk or opaque central part of the ovum, by a series of changes sufficiently well known; it is surrounded by a clear fluid, which is inclosed between it and the external pellucid membrane of the egg. By means of a lens, minute bodies may generally be perceived floating in the fluid, which by their motion serve to indicate the currents that take place in it; but with a little care the embryo may be extracted from the egg, and then the course of the currents along its surface can be rendered more evident by the usual means. A (*fig.* 310) is an enlarged view of the embryo

Fig. 310.



Embryo of the Frog.

of the Frog at the earliest stage at which I have detected the motion. The vertebral canal is just closed, and at the fore part of the body three ridges on each side indicate the commencement of the gills. The arrows point out the course of the currents. They proceeded backwards along the dorsal surface, diverging in a direction downwards and backwards on the sides. They were visible but weaker on the abdominal surface. B represents the embryo farther advanced, the currents have nearly the same direction but are better marked, they are strongest on the lateral eminences of the head which correspond to the future gills. In the embryo of the Newt, the phenomena are in a great measure similar; the currents seemed, however, to begin and to continue most vigorous on the abdominal surface; they are more particularly described in the paper referred to.

On extracting the embryo of the Frog, and viewing its surface in profile with Wollaston's doublet, moving cilia may be perceived on various parts. They appear like a transparent undulating line on the surface, and, though very minute, are so distinct as to leave no doubt of their existence.

No one can fail to perceive the analogy which subsists between the phenomena just described, and those which occur in the ova of Zoophytes and Mollusca. I have not been able distinctly to perceive a rotation of the embryo of the Batrachia, as observed in the other instances, but Purkinje and Valentin state that they have seen it, and Rusconi observed that the embryo of the Frog, when extracted from the ovum, turned round in a certain direction, which motion he supposed to be produced by water entering and issuing through pores in the skin.*

The phenomena in the Batrachian larvæ have since been observed by Müller,† Raspail,‡ and Purkinje and Valentin.§ The last mentioned naturalists also distinguished the cilia and perceived the motion within the egg.

Adult Batrachia.—The ciliary motion was discovered in the adult Batrachia by Purkinje and Valentin; indeed, it may not be improper again to state that the discovery of the phenomena in adult Reptiles generally, and in Birds and Mammiferous animals, is due to these physiologists.

According to their account, the ciliary motion in the Batrachia, as well as in all other vertebrated animals in which they have discovered it, occurs in two situations within the body, viz. on the lining membrane of the respiratory organs and on that of the genital organs of the female. They state that it exists over the whole internal surface of the lungs, and in the nose, mouth, and pharynx, extending as far back in the throat as the glottis, but no farther. They say nothing of the direction of the impulsion. Again, in the female, they discovered the motion on the internal surface of the oviduct. The result of my own examination of the Newt, Frog, and Toad is somewhat different. In all the three I found the ciliary motion very distinct in the mouth, throat, and gullet; in none could I perceive it in the lungs, notwithstanding very careful trials. In regard to the oviduct I have examined it only in the Newt, and although I could perceive something like the motion on the edges of its superior orifice, I could not detect it on the internal surface of the tube.||

* Sur le Developpement de la Grenouille Commune. Milan, 1826.

† Burdach's Physiologie, Bd. iv. p. 434.

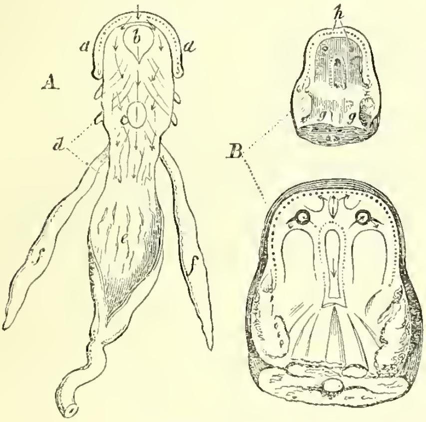
‡ Chimie Organique, 1833, p. 250.

§ Op. cit.

|| Edin. New Phil. Journal, xix.

The ciliary motion in the mouth and throat occurs all the way from the opening of the mouth to the termination of the œsophagus. Its extent and the direction of the impulsion are easily ascertained by means of powdered charcoal; they are pointed out by the arrows in the adjoining figures, A and B (*fig.* 311),

Fig. 311.



Salamander.

which are taken from the Newt, the appearances in the Frog and Toad being not materially different. *a* is the lower jaw detached from the head, *b* the tongue, *c* the glottis, *d* the œsophagus cut off from the head (at *g*, *g*, *fig.* B), and laid open from above, *e* the stomach, and *f*, *f*, the lungs. The general course of the impulsion, or, if in this case we might so express it, the currents, is longitudinal; they begin at the symphysis of the lower jaw and extend to the lower end of the œsophagus, where they terminate abruptly at the entrance of the stomach, thus differing from the description given by Purkinje and Valentin; but it is worthy of notice that these observers describe the motion in the Tortoise and Serpent as extending the whole length of the œsophagus. At particular parts the impulsion follows the direction of the plaits of the lining membrane. Figure B represents the head and the roof of the mouth, from which the lower jaw has been separated. On this part of the mouth also the general course is longitudinal, from before backwards; at the nostrils *h*, *h*, the particles are drawn in at one edge and issue at the other, as indicated in the outline of figure B.

As regards the use of the ciliary motion on the internal membranes of the Batrachia, we can scarcely doubt that one purpose is to convey onwards the secretions of these membranes in the direction indicated. It is not impossible also that it may have some more intimate connection with the respiratory process; but on this point we have not as yet sufficient grounds for forming a probable opinion.

Sauria, Ophidia, and Chelonia.—The authors mentioned describe the appearances in these reptiles as being similar to what they have found in Batrachia. The ciliary motion occurs in the oviduct and in the nose, mouth, pharynx, Eustachian tube, and inner surface of the lungs. In the Serpent and Tortoise they state that it extends along the gullet to its termination at the stomach, as we have seen to be the case in the Batrachia. The motion of the cilia is remarkably vivid in the mouth of the Serpent, and in the Tortoise it endures for several days after death, not ceasing till the parts are destroyed by putrefaction.

B. *Birds.*—The same physiologists have discovered the phenomena in thirteen species of Birds, belonging to five different orders; and as they met with it in every species submitted to examination, they infer that it exists in all.

In Birds, as in other Vertebrated animals, the motion shows itself on the lining membrane of the oviduct and that of the respiratory organs. It was detected in the nasal cavities and Eustachian tube, in the windpipe and its divisions, even in the smallest branches capable of investigation, and on the internal surface of the large sacs or receptacles into which the air penetrates. No trace of it could be found in the mouth and pharynx. In regard to the direction of the impulsion, the authors state that in the oviduct they had found it to be from the internal towards the external extremity of the tube, and in the windpipe from its orifice towards its branches, or from without inwards, at least they so observed it once in the domestic Fowl. The phenomenon exists in the fœtus of the bird, having been distinctly seen in the fœtal pigeon near the full period.

C. *Mammalia.*—An accidental observation led Purkinje and Valentin to discover the ciliary motion in Mammalia, and they followed out that discovery by extending their inquiries to other vertebrated animals. While examining the Fallopian tube of a rabbit that had been recently impregnated, in order to discover the ova, they chanced to observe small portions of the mucous membrane of the tube turning round, and moving briskly, and recognized the appearance as an instance of ciliary motion. The whole uterus and organs of generation generally were then diligently searched, and these motions were discovered throughout their entire extent, though of very different degrees of intensity in different places. They were particularly brisk in the tubes, less so in the cornua of the uterus, still less in the conjoined parts of the organ, most lively of all on its swollen and dark red lips, and of considerable strength in the vagina. After finding the same appearances in the oviduct of Birds and Reptiles, they succeeded also in discovering it in the lining membrane of the air-passages in all the three classes. In Mammalia the ciliary motion of the respiratory organs occurs on the mucous membrane of the nose and its sinuses, and that of the Eustachian tube, also on the lining membrane of the lower part of the larynx, the trachea, and bronchial tubes, extending to their smallest divisions capable of examination. No trace of it can be found in the glottis, nor in the mouth and pharynx. It was also sought for unsuccessfully in the lachrymal passages.

The authors mentioned have now examined it in twelve species of Mammalia, and have found the same appearance in all of them; they add that, although they have had no opportunity of inspecting the parts in the human body so soon after death as to see the cilia in motion, yet by covering the surfaces to be examined with blood, which preserves the appearance longer than any other fluid, they were able on examination, thirty hours after death, satisfactorily to distinguish the cilia both in the nose and windpipe.

I have seen the phenomena in the nose, trachea, and Fallopian tubes of the Rabbit, and in the trachea of the Dog.*

According to Purkinje and Valentin the motion occurs in the uterine mucous membrane, both in the impregnated and unimpregnated state; but in gravid animals it appears only on those parts of the uterus which are not adherent to the chorion or external envelope of the fœtus. The direction of the impulsion they state to be from the internal extremity of the tube, towards the orifice of the vagina. It seems wanting on the genital membrane of young animals. On the other hand, it occurs in the respiratory passages of the fœtus, it was detected in fœtal calves and lambs, and in fœtal pigs not more than two inches long. The authors could not with certainty distinguish the direction of the impulsion in the air-passages of Mammalia. In some parts of the nose of the Rabbit, I have been able to trace it clearly enough by means of charcoal powder, the parts being placed in tepid water. On the inferior turbinated bone the grains of powder were slowly carried forwards, following the direction of the projecting laminæ of the bone. On breaking open the maxillary sinus and trying its lining membrane in the same way, the impulsion seemed to be directed towards the back part of the cavity, where its opening is situated. By the same means I traced the direction in the windpipe of a young dog a few days old; the impulsion was best marked on the posterior part of the tube, and there it was obviously directed towards the larynx, the direction being thus different from what Purkinje and Valentin observed in the domestic Fowl.

PART II.

1. Summary of the animals in which the ciliary motion has been discovered.

From the foregoing facts it appears that the ciliary motion is a phenomenon which prevails most extensively in the animal kingdom, having been found in the highest as well as the lowest members of the Zoological scale. Among Vertrebated Animals it has been discovered in Mammalia, Birds, and Reptiles, viz. the *Batrachia*, *Sauria*, *Ophidia*, and *Chelonia*. Of the Invertebrata it has been found in Mollusca, viz. *Gasteropoda*, *Conchiferous acephala*, and *Tunicata*; in Annelida, viz. *Aphrodita*, *Arenicola*, and many *Tubicolar worms*, also in *Planariæ* and *Naiades*; in Echinodermata, viz. the *Asterias* and *Echinas*; in Actiniæ; in Medusæ; in Polypi; in Sponges; and in Infusoria. It is a remarkable fact that no trace of it has been observed in Fishes. I at one time supposed that the pendent filaments of the gills of the fœtal Skate and Shark might probably be found to exhibit it; but my friend, Dr. Allen Thomson, has carefully inspected those of the Skate without being able to perceive any appearance of it.*

2. Organs or parts of the body in which the ciliary motion has been ascertained to exist.

These may be referred to four heads, viz. the skin or surface of the body, the respiratory, alimentary, and reproductive systems. Its use in all these cases, or the function in general of the cilia, is to convey fluids or other matters along the surface on which the cilia are placed, or, as in the Infusoria, to carry the entire animal through the fluid.

a. Surface of the body.—Cilia have been found on different parts of the external surface, in Batrachian larvæ, in Mollusca, Annelida, Echinodermata, Actiniæ, Medusæ, Polypi, and Infusoria. Their function in this situation is various; in most cases it is evidently respiratory, but in many instances it is also locomotive, as in Infusoria and Medusæ, or prehensile, as in Infusoria and Polypi; and perhaps it is in some animals subservient to the sense of touch or smelling, as may be conjectured with regard to the cilia on the tentacula of some Mollusca.

b. Respiratory system.—The ciliary motion has been observed on the lining membrane of the air-passages of Mammalia, Birds, and Reptiles; and there, whatever may be its other uses, it at least serves to convey the secretions along the membranes, together with foreign matters, if any are present. It exists also on the external gills of Batrachian larvæ, and on the gills of Mollusca and Annelida. In other Annelida, in Echinodermata and Actiniæ, it is found on the external surface of the viscera and on the parietes of the cavity containing them, to which cavity the water has access. The pores and canals of the Sponge are probably both respiratory and alimentary passages, and under this head we must refer again to the cilia on the external surface of Medusæ, Polypi, and Infusoria, as belonging partly to the respiratory system. The use of the ciliary motion on the respiratory organs of animals with aquatic respiration is obviously to renew the water on the respiring surface.

c. Alimentary system.—The motion occurs in the mouth, throat, and gullet of Reptiles, in the entire alimentary canal of Mollusca, on

* Edin. New Philos. Journal, xix.

* Since the above was written, a short notice has appeared in "l'Institut" of 16th December, 1835, of the Transactions of the Leopoldine Academy for 1834-35, from which it appears that Purkinje and Valentin have at last succeeded in detecting the phenomenon in Fishes. They found it in the organ of smelling and the internal genital organs of the female. No further particulars are stated.

the internal surface of the intestine and cœcal appendages of the Aphrodita, within the stomach and cœca of the Asterias, in the stomach of the Actinia, in the canals of the Sponge, which no doubt belong partly to the alimentary system, and in the mouth, throat, stomach, and intestine of several Polypi. It is not easy to see the purpose of the motion in all these cases. In some it may merely convey secreted matters along the surface of the lining membrane; in Polypi it agitates the food within the alimentary cavity, and in several instances it seems almost to serve in place of ordinary deglutition, to carry food into the stomach.

d. Reproductive organs.—The phenomenon occurs on the mucous membrane of the Fallopian tubes, uterus, and vagina of Mammalia, and of the oviduct in Birds and Reptiles. From the direction of the impulsion being from within outwards, it is difficult in the meantime to assign any other office to the cilia in this situation than that of conveying outwards the secretion of the membrane, unless we suppose that it also brings down the ovum.

The phenomenon has been sought for in other parts of the body, but hitherto without success. Purkinje and Valentin state that on examination they could not find it in the following parts of vertebrated animals, viz. the skin, serous membrane, the alimentary canal, (except the mouth and gullet of Reptiles,) the gall-bladder, the biliary and pancreatic ducts, the urinary organs, the seminal vesicles and ducts, the conjunctiva, cornea, and iris, the internal surface of the bloodvessels, the globules of the blood and lymph, the chorion, amnion, allantois, and yolk-sac of Birds. I have also repeatedly examined the fœtal membranes of the common Fowl, and with the same result.

3. *Of the ciliary motion in the embryo.*—According to Purkinje and Valentin the ciliary motion of the genital mucous membrane does not appear in the fœtus, nor until the animals have made some approach to the adult state; that of the respiratory passages on the other hand becomes apparent in the embryo long before it attains maturity. The ciliary motion, however, to which we would here refer is that which occurs at a much earlier period on the surface of the embryo of many animals, and generally causes it to perform a rotatory movement within the ovum. It has now been observed in the ova of Batrachia, Mollusca, Actiniæ, Polypi, Sponges, and Infusoria. While the embryo is contained within the ovum, the cilia produce a current in a certain direction along its surface, or cause the whole embryo to move in the opposite direction; hence the very remarkable rotatory motion which occurs in many instances, and which is so well marked in the Snail. When it has escaped from the egg, the embryo moves about in the water by means of the cilia, as happens also with the naked gemmules of the Sponge after they are discharged from the parent. The ciliary motion is subservient to the respiration of the embryo, by renewing the contact of the water or fluid contained in the egg on the respiring surface, and in some instances, the Mollusca for example, the motion is observed to be especially strong at the part where the respiratory organ is afterwards developed. When the embryo quits the egg, the cilia serve also for locomotion, and by this provision the gemmules of fixed zoophytes are disseminated, and conveyed to situations suitable for their future growth.

4. *Figure, structure, and arrangement of the cilia in general.*—The cilia are best seen when their motion slackens; their shape, size, arrangement, and manner of moving may then be distinguished with tolerable accuracy, at least in the larger sort. Their figure is in general that of slender, conical, or sometimes slightly flattened filaments, broader at the base or root, and tapering gradually to the point. Their size differs greatly on different parts even of the same animal, but on corresponding parts of different individuals of the same species their size seems to be the same. The largest I have measured are those on the point or angle of the branchial laminæ in the *Buccinum undatum;* they are at least $\frac{1}{500}$ of an inch long. I have not attempted to determine the exact size of the smallest, but Purkinje and Valentin state it at 0.000075 of an inch, while they make the largest they have met with only 0.000908 in., which is considerably less than I have found them; but they had no opportunity of examining marine animals, in which, generally speaking, the largest cilia are met with. In the Sea-mussel the darker-coloured cilia are about $\frac{1}{1000}$ of an inch long, the others considerably less.

The cilia are very generally arranged in regular order. In some cases they are placed in straight rows, as on the gills of the Mussel; in others they form circles or spiral lines, as in many Infusoria; and Purkinje and Valentin state that in animals of the higher orders the most prevalent mode of arrangement is in spiral lines or ridges. They are generally set close together in the same row; on the gills of the Sea-mussel I find there are seven or eight of the larger cilia in the length of $\frac{1}{1000}$ of an inch, or about seven or eight thousand to the length of an inch, but in other cases there are many more. In some instances they are erect, or at right angles to the surface on which they are planted, in others inclined, and then it would seem that the inclination is in the direction of the currents which they produce. In some parts they are straight, in others curved, not only when in action, but also when at rest, and the points are bent in the same direction in which the currents flow.

The substance of the cilia is transparent, and for the most part colourless; in some, however, it is coloured brown or yellowish brown. It appears as if homogeneous, even when highly magnified, and no fibres or globules are distinguishable in it. It seems to vary somewhat in consistency, for the cilia on some parts appear extremely soft and pliant, and on others comparatively firm and elastic, though still abundantly flexible.

There is a peculiarity in the form of the cilia in some animals, of which the Beroë and other

Ciliograde Medusæ afford a good example. In these, in place of cilia of the usual form and arrangement, there are rows of broad flattened organs, each of which is made up of several simple filaments joined together by a common base, according to Eschscholz, or according to Dr. Grant by a connecting membrane in their whole length. The entire organ is raised or depressed at once, so that the filaments are all moved simultaneously, like the eye-lashes. The compound cilia in some of the Rotatoria, described by Ehrenberg, are probably of the same nature.

5. *Of the appearance of the cilia in motion.*—On examining these organs with a lens of $\frac{1}{35}$ inch focus, when their motion is not very rapid, the manner in which the individual cilia move may be distinguished with tolerable certainty. Most commonly they have a fanning or lashing motion, that is, the cilium is bent in one direction and returns again to its original state. The flexion takes place chiefly at the base or root, but not wholly there, for the rest of the organ is obviously bent and altered in figure; nay, the more elastic cilia, when their motion abates in intensity, appear sometimes to bend only near the point, the base and adjoining part remaining motionless.

When a number of cilia are affected in succession with this motion, the appearance of a progressive wave is produced, and as in such a case they are again and again moved in the same way at very short intervals, successive waves proceed along them in the same direction, which might be compared to those produced by the wind in a corn-field. Such at least seems to be the true explanation of the undulatory motion which so often occurs, although it must be confessed that the motion of the cilia individually cannot be distinctly seen when the undulation is most perfect. The undulations succeed one another along a range of cilia with great regularity, and except in the Rotifera, and perhaps some other Infusoria, they seem always to maintain the same direction in the same parts.

Purkinje and Valentin describe the motion of the individual cilia as being more frequently rotatory, or, as they term it, infundibuliform; and Ehrenberg states this to be the common mode in the Infusoria; the cilium describing a circle with its point, while the base is the centre of motion. From my own observation, however, I would be inclined to infer that this motion is by no means the most common.

6. *Duration of the ciliary motion after death and in separated parts.*—The continuance of the ciliary motion for some time after death, and the perfect regularity with which it goes on in parts separated from the rest of the body, are facts which have been already repeatedly stated, and sufficiently prove that the motion is quite independent of the will of the animal, and also that it is not immediately influenced by the circulation of the blood, even in the respiratory organs.

The time which it continues after death differs in different species of animals, and also, but in a much smaller degree, in different parts of the same animal. Its duration is influenced also by the temperature of the air, and by the nature of the fluid in contact with the surface. In Mammalia and Birds the period varies from half an hour to four hours, being longer in summer than in winter; but it is still further prolonged when the parts are covered with blood. In the gills of Batrachian larvæ I have seen the motion continue six hours; but of all vertebrated animals it is most enduring in the Tortoise, in which animal Purkinje and Valentin affirm they observed it fifteen days after death, when putrefaction was far advanced; the irritability of the muscles remained in the same animal for seven days. Among the invertebrata the River-mussel affords an instance of the great pertinacity of the motion, which ceases only when putrefaction has advanced so far as actually to destroy and dissolve the tissues.

7. *Effects of external agents on the ciliary motion.*—Steinbuch, Purkinje, and Valentin allege that on touching the parts, or giving them a gentle shock by merely striking against the object plate of the microscope, the motion is rendered brisker when it has become languid, or is even renewed in parts where it has ceased. They, however, attribute more importance to this fact than it seems to deserve; for it may be doubted whether the concussion in renewing the vivacity of the cilia does not act merely by removing obstacles which impede their play.

Electricity and galvanism produce no visible effect. A powerful discharge from a Leyden jar was made to pass through the River-mussel by Purkinje and Valentin without causing any change in the ciliary motion. Portions of the external gills of the Tadpole were subjected by myself to the same experiment and with a similar result, except when the surface was abraded, which occasionally happened with a strong discharge. I have exposed portions of the gill of the River-mussel while viewed with the microscope, to the influence of a galvanic battery of twenty-five pairs of three-inch square plates, charged with solution of salt, without being able to perceive the slightest effect on the motion of the cilia. The authors above mentioned obtained a similar result, both in the Mussel and the domestic Fowl.

The effect of temperature is different in warm and cold-blooded animals. In the former, according to Purkinje and Valentin, the motion stopped on exposure to a temperature of 43° F. while it went on at 54° F. On the other hand they found that in the Fresh-water Mussel it was not affected at 32° F.; and I found the same to be true of the Tadpole. A portion of the gills of the River-mussel, which I kept for five minutes in water at 96° F. shewed no change.

Acids, saline solutions, and other substances applied to the parts, differ in their effects according to the kind of animals submitted to experiment. Thus, for example, fresh water instantly arrests the motion in the Marine Mollusca, and also in other marine animals in which I have tried its effect, though a saturated solution of sea-salt destroys it both in salt and fresh-water species. Purkinje and

Valentin state the effects which they found to result from the application of various substances, but erroneously conceiving, from some preliminary trials, that the same substance produced the same effect in all animals, they confined their experiments to the Fresh-water Mussel. According to their experiments, which were made with a great many different substances, most of the common acid, alkaline, and saline solutions, when concentrated, arrest the motion instantaneously; dilution, to a degree varying in different substances, prevents this effect altogether, and a less degree of dilution delays it. The same is the case with alcohol, æther, aqua laurocerasi, sugar, and empyreumatic oil. Kreosote, muriate of baryta, sulphate of quinine, infusio pyrethri, and muriate of veratria, act less intensely. Hydrocyanic acid and watery solutions or infusions of belladonna, opium, capsicum, catechu, aloes, musk, gum-arabic, acetate of morphia, and nitrate of strychnia, produce no effect whatever. They accordingly infer that the substances affect the motion only in so far as they act chemically on the tissue.

The result of my own experiments differs from theirs in some points. In the River-mussel I found that hydrocyanic acid, containing ten per cent. of pure acid, invariably destroyed the motion. Solution of muriate of morphia, of medicinal strength, also arrested the motion in the Mussel, but not in the Batrachian larvæ. The motion on the gills of these larvæ also continues unimpaired in water deprived of air by boiling, or distilled, or impregnated with carbonic acid; a sufficient proof, it may be remarked, that it is independent of the chemical process of respiration.

In regard to the effect of animal fluids, the authors already mentioned state that bile arrests the motion, while blood has the property of preserving it much beyond the time that it lasts in other circumstances, at least in vertebrated animals; thus it continued three days in a portion of the windpipe of the Rabbit, which had been kept in blood. But it is singular that blood or serum, whether of Quadrupeds, Birds, or Reptiles, has quite the opposite effect on the cilia of invertebrated animals, arresting their motion almost instantaneously. Albumen and milk also possess the conservative property, though in a less degree.

8. *Effects of inflammation.*—Purkinje and Valentin excited inflammation artificially in the nose and vagina of rabbits, and are inclined to conclude from their experiments, which however are not numerous, that inflammation arrests the motion.

9. *Of the power by which the cilia are moved.*—It may next be inquired by what means or by what power the cilia are moved; and, in particular, whether their motion, like other visible movements in the animal body, is effected by muscular action.

Dr. Grant,* reflecting that in the Beröe a vessel conveying water runs beneath each row of cilia, and that, according to M. Audouin, in an allied genus of animals the water enters the cilia, is disposed to liken the motion of the cilia to that of the feet of the Echinodermata. He seems accordingly to think it probable that the cilia are tubular organs, which are distended and protruded by the injection of water into them from elastic tubes running along their base, in which the water is conveyed by successive undulations.

This view, however, seems scarcely reconcilable with the fact that the motion of the cilia continues in parts separated from their connexion with the rest of the body, portions so small that not more than two or three cilia are attached to them, and in which the operation of the supposed undulating tubes can scarcely be conceived.

Ehrenberg states that in the Infusoria he observed that the cilia were bulbous at the root, and that they were moved by small muscles attached to the bulb. Purkinje and Valentin also admit the existence of a bulb, and they conceive it likely that the cilia are moved either by muscular substance placed within the bulb, or by certain fibres which they believe they have discovered in the adjacent tissue. They describe these fibres as existing in the substance of the membranes or other parts supporting the cilia, being situated at the surface, straight and parallel, and appearing to be connected together by delicate cellular tissue; and they think it highly probable that they are of a muscular nature.

The whole phenomena of the ciliary motion seem to me most consistent with the notion that it is produced by muscular action. I must confess, however, that I have never seen the muscular fibres described, nor the bulbs; and perhaps the cilia are not moved merely by muscular fibres attached to their base, like the whiskers of the seal and cat, but may contain muscular substance throughout a greater or less portion of their length, by which they can be bent and extended; or perhaps they may in some instances be bent by muscular fibres, and resume their original shape and position by virtue of their elasticity.

We need not hesitate to admit that the ciliary motion is the result of muscular action on account of the smallness of the muscular apparatus necessary; for the researches of Ehrenberg on the Infusoria have brought to light examples of complex organization on as minute a scale as any here required. Nor need we hesitate on account of the great rapidity of action; for there are familiar instances of muscular motions of equal velocity. The continuance of the ciliary motion after death and in parts detached from the rest of the body, and its regularity in these circumstances, are appearances, startling at first, but which, though they differ in degree, may be fairly compared with those produced in similar circumstances by involuntary muscular action, and may be attributed to the same cause. Thus the different parts of the heart, which during life contract in a certain order independently of the will, continue to act in the

* Trans. of Zoological Society of London, vol. i. p. 11.

same regular order for a time, and in some animals for a long time, after death or separation from the body; and it is remarkable, although perhaps we are not warranted by observation to lay it down as a general rule, that there is a correspondence in the duration of the ciliary motion after death and the persistence of muscular irritability. In the Tortoise, for instance, in which it is well known that the irritability of the heart and other muscles endures remarkably long after death, the ciliary motion is also of extremely long continuance; while in Mammalia and Birds, the ciliary motion and muscular irritability are both comparatively soon extinguished.

On the whole, therefore, without laying any stress on the alleged discovery of a muscular apparatus by Ehrenberg and the other authors mentioned, we may venture to conclude that the facts known respecting the motion of the cilia are all reconcilable with the opinion that it is produced by muscular contractility.

10. Strange as it may seem, after what has been said, some observers maintain that the cilia have no real existence, even in cases where the appearance of them is the most perfect, and that the whole is an optical deception. I allude particularly to Raspail; according to him the water which quits the respiring surfaces has, in consequence of the change produced in it by respiration, acquired a different density, and consequently a different refractive power from the surrounding fluid; it therefore produces the appearance of lines or streaks at the surface of the parts, which streaks are the supposed cilia. It is scarcely necessary to repeat that the cilia are seen when at rest, when all motion of the water has ceased, and that they are evident in circumstances in which no interchange of materials can take place between the tissue and the water in contact with it; and indeed, after the details already given, it is needless to say more in refutation of this view.

11. *Of the motion caused in fluids by the cilia.*—One of the most remarkable characters of the motion produced in water and other fluids by the ciliary action, is its definite direction, which, except in some of the Infusoria, appears to be always the same in the same parts; at least I have never been able to perceive any exception to this rule. Appearances would rather lead to the belief that in the Infusoria the motion of the cilia is under the influence of the will, which would account for this and other possible cases of exception.

We have hitherto taken it for granted that the currents in the water are owing to the mechanical effect of the moving cilia, without formally adducing proofs in support of the opinion; but at the same time the details already given must have served as such. The currents cease when the motion of the cilia stops, they are strong and rapid when it is brisk, and feeble when it languishes; and though there are modifying circumstances or perhaps exceptions, yet in general the magnitude and velocity of the current seem to be proportionate to the size and activity of the cilia. It is true that while doubts remained as to the existence of cilia in several well-marked instances where the water unequivocally received its motion from the surface over which it flowed, and, independently of any visible contractions of the animal tissue, there was also considerable room to doubt whether, even in the cases where cilia were manifest, the effect of these organs was wholly mechanical, and whether the motion of the water was not rather due to some peculiar impulsive power in the tissue, differing from mechanical action. But more extended observation has almost wholly removed these exceptions, while it has considerably increased the number of conforming instances, insomuch that there seems at present no necessity for having recourse to any other explanation of the motion of the fluids than that it is produced by the action of the cilia, and that their action is the result of muscular contractility, a known property of animal tissues.

The phenomena of the ciliary motion seem therefore of themselves to afford no countenance to the notion of a peculiar impelling power of the animal tissue, in virtue of which fluids are visibly moved along its surface, independently of impulse communicated to them mechanically by cilia or by contraction of inclosing solids; nor am I aware of other facts which either alone, or viewed in connexion with the former, warrant such a notion. But as some physiologists believe in the existence of such a power, and found their opinion, at least partly, on alleged examples of visible motions of fluids in organized bodies, produced without cilia and independent of contraction of the solids, it may not be amiss here shortly to consider the principal facts which have been adduced as instances of this kind.

First, Three cases have been already mentioned in which currents, more or less resembling those produced by cilia, take place on surfaces on which cilia have not been detected; these are the currents in the Sponge, those of the Tubularia indivisa, and those within the stem and branches of Sertulariæ. In regard to the Sponge, it is true that cilia have been diligently sought for and without success; still, considering the difficulty of the investigation, it is not impossible they may exist in some part of the passages through which the water runs, though not yet discovered, especially as the ova possess evident cilia. With respect to the currents described by Mr. Lister within the stem of the Tubularia, it will be seen, on referring to the account of these, that farther observations would be required to settle the points here in question, viz. whether the floating particles receive their impulse from the surface over which they move independently of any contraction of the stem, and whether or not that surface is covered with cilia. To decide these points satisfactorily it would be necessary to lay open the tube and make trial of detached portions of the tissue as in other instances. The same remark is in a great measure applicable to the currents in the stem and branches of Sertulariæ. Indeed both instances have been described above only because of their seeming analogy with the rest, but further investigation is still required to determine their true nature. Neither these, therefore, nor the Sponge afford unequivocal examples of the peculiar motion of fluids alluded to taking place independently of cilia. Of course we may pass over without notice the cases in which the appearance of the moving cilia has been mistaken for a circulating fluid,* or ascribed to other causes than the real one, and their existence erroneously denied.

Secondly, It is well known that in cold-blooded animals the blood continues to move in the capillary vessels for some time after the heart has been cut out. This motion for the most part goes on at first steadily from the smaller to the larger vessels in the arteries as well as the veins, and afterwards becomes oscillatory. Haller, who particularly investigated the phenomenon, was of opinion that it could not be attributed to contraction of the large vessels, to gravitation, nor to capillarity; he therefore attributed it to some unknown power which he conceived to be exerted by the solid tissues on the blood and also by the globules of blood on each other, and to this power, until farther investigation should elucidate its nature, he gave the name of attraction. The same opinion or a modification of it has been taken up by succeeding physiologists; accordingly many maintain the existence of a peculiar propulsive power in the coats of the capillary vessels different from contractility, or that the globules of blood are possessed of the power of spontaneous motion. Among others, Dr. Alison has adopted and extended this view in so far as he regards the motion of the blood in the capillaries as one of the effects produced by what he calls vital attraction and repulsion, powers which he conceives to be general attributes of living matter, or at least to manifest themselves in other processes of the living economy besides the capillary circulation.

The motion in question has certainly not been as yet satisfactorily accounted for by referring it to the operation of known causes. At the same time we can scarcely admit that the influence of such causes has been wholly avoided in the experiments in which the phenomenon has been observed. It is not impossible, for example, that a certain degree of agitation may be occasioned in the blood by the elastic resilience of the vessels reacting on it, after the distending force of the heart has been withdrawn. The necessity of the case therefore, though great, seems scarcely such as alone to warrant the assumption of a peculiar attractive or repulsive power acting on the blood at sensible distances, of whose existence in the animal economy we have as yet no other evidence. It may be remarked, finally, in regard to the phenomenon alluded to, that it cannot properly be termed a continuance of the circulation, for the blood does not necessarily preserve its original course, nor indeed any constant direction. (See CIRCULATION.)

Thirdly, In several plants motions have been observed in the fluids which are contained in their cells or vessels in determinate directions, and seemingly independent of any contraction of the parietes of the containing cavities. The best known example of this is in the Chara. Its jointed stem consists of a series of elongated cells, which contain a clear fluid with globules suspended in it. The globules are moved up one side of the cell and down the other in continual circuit. No contraction can be perceived in the parietes of the cells, which are indeed of a rigid texture, and this mysterious movement has therefore been ascribed to some unknown and invisible impelling power. It is doubtful, however, whether the motion can go on unless the cell is entire, the experiments of different observers on this point being contradictory, and it certainly has never been shewn that separated portions of the tissue continue to excite the motion. In this state of knowledge on the subject we can scarcely admit this or similar motions of vegetable juices as unequivocal examples of the operation of an impulsive power of the kind referred to; and even on the contrary supposition it does not follow that such a power exists in animals.

On the whole therefore, from what has been said regarding the several examples adduced, we may conclude that they do not afford unequivocal evidence of visible motions being produced in fluids in the animal body, independently of contractions of containing solids or of the action of cilia; and, consequently, that viewed in reference to the ciliary motion, they form no adequate reason for doubting that the fluid is moved mechanically by cilia.

I may conclude this article by observing, that though the general existence of the ciliary motion in the Animal Kingdom is already sufficiently established, yet many particular instances of it must still remain to be found out, especially in invertebrated animals; and whoever has opportunities and inclination to cultivate this field of inquiry will find his labour rewarded by much curious and interesting discovery.

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* As by Baker, Guillot, and others.

in Abhandl. der königl. Akad. der Wissensch. zu Berlin für 1816-1817. **Gruithuisen*, in Salzb. Med. Chir. Zeitung, 1818, Bd iv.; Nov. Act. Acad. Cæs. Leop. vol. x. *G. R. Treviranus*, Vermischte Schriften, 4to. Bd iii. Bremen, 1820. *Hugi*, in Isis for 1823. **Carus*, Von den äussern Lebensbedingungen der weiss-und kaltbluetigen Thiere, 4to. Leipz. 1824; Nov. Act. Ac. Cæs. Leop. vols. xiii. and xvi. *Fleming*, in Mem. of Wernerian Society, vol. iv. **Huschke*, in Isis for 1826. **R. Grant*, in Edin. Phil. Journal, Edin. New Phil. Journ., Edin. Journal of Science, and Trans. of Zoological Society. *Sir E. Home*, Phil. Trans. 1827. **Raspail*, Mém. de la Soc. d'Hist. Nat. de Paris, 4to. vol. iv. 1827; Chimie Organique, 8vo. Paris, 1833. *Meyen*, Isis for 1828. *E. H. Weber*, in Meckel's Archiv. 1828. *Fr. Eschscholz*, System der Acalephen, 4to. Berlin, 1829. *Dutrochet*, in Annales des Sc. Nat. t. xv. 1828. **W. Sharpey*, in Edin. Med. and Surg. Journal, vol. xxxiv. July, 1830. *Guillot*, in Magendie Journal de Physiologie, xi. 1831. **Ehrenberg*, Ueber Infusorien, in Abhandl. der k. Acad. der Wissensch. zu Berlin für 1830 and 1831, Müller's Archiv. i. 1834. *R. Wagner*, Isis for 1832. *Jo. Müller*, Handbuch der Physiologie, Bd i. 8vo. 1833. *H. Rathke*, in Dorpater Jahrbücher, &c. Bd i. 1833. **Jos. J. Lister*, in Phil. Trans. 1834. **J. E. Purkinje & G. Valentin*, in Müller's Archiv. Bd i. translated in Dublin Journ. of Med. and Chem. Science for May, 1835, and in Edin. New Phil. Journ. vol. xix. July, 1835; also, by the same authors, Commentatio Physiologica de Phenomeno Motus vibratorii continui, &c. 4to. Wratislav. 1835, (the only systematic treatise on the subject.)

(W. Sharpey.)

CIRCULATION (in Physiology), *(Circulatio, Circulus, Circuitus Sanguinis;* Fr. *Circulation du Sang;* Germ. *Blutlauf;* Ital. *Circolazione del Sangue;)* designates in its more extensive signification the course through organised beings of their nutritious fluid; as limited to man and the higher orders of animals, the course of the blood from the heart to the most minute vessels, and from these back to the heart.

By modern writers on physiology the circulation of the blood is generally included under the nutritive functions, because one of the most important purposes served by the motion of this fluid through the various textures and organs of the body is the supply of those new ingredients which are necessary to carry on the process of growth and the changes of nutrition. A very slight acquaintance with animal physiology teaches us, however, that the function of circulation has another very important and immediate use, viz. the support of that condition of the textures and organs which is necessary to enable them to exercise their vital properties. It was on account of the apparent necessity of a constant supply of blood for the support of the animal powers, that Galen placed circulation, along with respiration, among the vital functions.

In the following article it is intended to describe more particularly the course of the blood in the human body and the powers by which it is moved, and also to state the general facts ascertained regarding the function of circulation in other animals.

For the sake of clearness it will be necessary to divide the subject into several departments. The first of these will comprehend a description of the course of the blood in man; the second of its course in animals. In the third will be considered the phenomena presented by the blood during its motion, the properties of the organs in which it circulates, and the powers by which it is propelled; and in the fourth will be mentioned the more important circumstances connected with the other functions which modify the circulation.

The term circulation applied by its celebrated discoverer, Harvey, to the motion of the blood, is sufficiently expressive of the general fact that this fluid, or the greater part of it at least, in being carried through the body, moves in a circular course, or, that in performing its journey through the body, the blood always returns to the same place from which it set out. The term is equally applicable to the function by which a supply of nutritious fluids is kept up in the lowest animals, in which a progressive motion of a fluid of the nature of blood takes place, as well as in the highest; for in nearly the whole of them there is a central part of the circulatory organs, which forms the rallying point, as it were, of the rest, from which the blood begins its course and to which it is brought back, in a longer or shorter period of time, after having passed through the different organized parts.

I. Course of the blood in man.

The organs of circulation consist of the heart, arteries, veins, and capillary vessels. We refer the reader to the articles on these different organs for all details relative to their anatomical structure.

In man and warm-blooded animals there are two passages through the interior of the heart, through each of which a stream of blood is propelled at the same time, so that the heart is alternately receiving and giving out a certain quantity of blood upon each side.

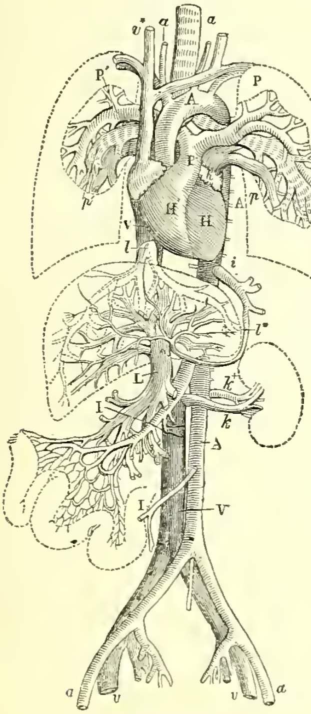
The two auricles serve as receiving cavities for the blood which is constantly flowing into the heart from the veins or those vessels which have the office of returning blood to the centre of the circulation. By the contraction of the muscular parietes of the auricles, the blood is propelled from these cavities into the ventricles, which, in their turn, contract with force and thus propel their contents into the arteries, or those vessels which serve to transmit blood outwards from the centre of the circulatory organs. The auricles and ventricles of the opposite sides acting simultaneously, and the size of these cavities on the right and left sides of the heart being nearly equal, the quantity of blood which is made to pass through each of them at one and the same time must also be nearly equal.

The cavities on the left side of the heart are adapted to propel the blood into those arteries which are subservient to the nutrition of the body, while those on the right side of the heart send the blood to the lungs for the purposes of respiration. The construction of the heart and the connection of its parts with the arteries and veins are such that the whole of that blood which has served the purposes of nutrition, and the other uses for which the blood is destined throughout the body, on being returned to the heart, is directed by the cavities on the right side of that organ to the lungs, and made to pass through them before returning to the left side of the heart to repeat its course through the nutritive vessels of the body.

In all those animals in which there exists a disposition of the heart and bloodvessels such as that described, the circulation is said to be *double*, because the blood is moved in two circles at once, and the respiration is said to be *complete*, because the whole of that blood which has passed through the nutritive vessels of the body is subjected to the respiratory action of air in the lungs.

The blood returned from the lungs of a bright red colour, or arterial blood, on being expelled from the left ventricle (*fig.* 312, *H*)

Fig. 312.*



Circulation in Man.

* In all the figures relating to the circulation in different animals the same letters indicate corresponding parts as follows :

H, the heart or the common ventricle; *h*, the common auricle;
A, the aorta or trunk of the systemic arteries; *a*, its branches; *a**, the carotids.
V, the great systemic veins or vena cava inferior; *v*, its branches; *v**, the vena cava superior; *c*, the capillary vessels;
P, the pulmonary artery; *p*, the pulmonary vein;
B, the branchial artery; *b*, the branchial vein;
D, the ductus arteriosus; *d*, ductus venosus; *f*, foramen ovale;
U, umbilical arteries; *u*, umbilical vein;
I, arteries of the intestine or alimentary canal; *i*, the cœliac artery;
L, vena portæ; *l*, hepatic vein; *l**, hepatic artery;
K, advehent renal veins; *k*, renal veins; *k**, renal artery.

In those instances in which the parts are double, those on the right side are distinguished by the accentuation of the letters indicating them, thus P′ right pulmonary artery, P left ditto.

We beg to remind the reader that most of these figures are merely plans, and that strict anatomical accuracy is not to be looked for in them.

by the muscular contraction of that cavity, passes into the aorta or great artery of the system (*A*), and is distributed in various proportions to all parts of the body by the branches of the aortic trunk (*a*) and their infinitely minute ramifications. The smallest arteries lead, by an intermediate set of minute tubes to which the name of capillary vessels is given, into the systemic veins (*v*), all of which (the veins of the intestinal canal excepted) joining gradually together into larger and fewer branches, form at last the great trunks of the superior and inferior venæ cavæ (*V*, *v**), which carry back to the centre of the circulation the whole of the blood that had passed from the left ventricle into the aorta.

In passing from the arteries to the veins through the capillary vessels, the properties of the arterial blood are changed; its colour is altered from bright scarlet to dark purple, it expends some of its substance in the nourishment of the textures, and a considerable quantity of its thinner part transudes through the small vessels, constituting the lymph that is taken up by the absorbent vessels. The venous or dark blood, as it approaches the heart upon its return, has its composition further changed by its admixture with the chyle or imperfectly formed blood, which is the product of digestion, and which is poured along with the lymph from the thoracic duct into the great veins of the head and superior extremities.

By the changes thus produced in its composition, &c., the venous blood which returns to the heart is rendered unfit for nutrition, until it has been acted upon by the atmospheric air in the lungs, which restores to it its bright red colour and arterial composition and properties.

The great systemic veins are therefore connected with the right side of the heart (*H′*), and the stream of venous blood brought by them to the right auricle (*h′*), next issues from the heart by the pulmonary artery (*P*), into which it is propelled by the contraction of the right ventricle (*H′*) as it passes through that cavity. The minute branches of the pulmonary arteries and veins (*P*, *p*), and the capillary vessels by which they communicate with one another, are wholly distributed on the membrane lining the air-cells of the lungs. In passing through these vessels then, the venous blood is exposed to the action of the atmospheric air contained in the pulmonary cells; and, after having acquired arterial properties, is returned to the centre of the circulation by the pulmonary veins (p). The left auricle (h) receives the newly arterialized blood from the pulmonary veins, and transmits it to the left ventricle (H), from which it is ready to start again, when the ventricle contracts, on the same course as has just been described.

In this double circulation, the path which the blood traverses in passing from the left to the right side of the heart through the aortic arteries and the corresponding veins, has been called the *greater* or *systemic* circulation: and the route of the blood from the right to the left side of the heart through the pulmonary arteries and veins has been termed the *lesser* or *pulmonic* circulation. The names of pulmonic and systemic, indicating the parts of the body in which each of these circulations respectively occurs, are on the whole preferable to the corresponding terms of lesser and greater.

There is still one part of the course of the blood to be mentioned, viz. that of the venous blood of the principal abdominal viscera through the liver, or what has been termed the system of the vena portæ.

The blood supplied by the cœliac and mesenteric arteries (I, i) to the abdominal viscera is not returned directly to the heart by their corresponding veins, as occurs in other parts of the body. The veins of the stomach and intestinal canal, of the spleen, pancreas, mesentery, omenta, and gall-bladder, unite together below the liver into one large vessel (L), the trunk of the vena portæ, which branches out again and distributes to the liver by its ramifications the whole of the venous blood coming from the above-mentioned organs. The blood of the vena portæ, being joined in the minute branches by that of the hepatic artery (l^*), passes into the smallest ramifications of the hepatic veins, by the principal trunks of which (l), the venous and arterial blood circulated through the liver is carried to the inferior vena cava, and thus reaches at last the right side of the heart.

Proofs of the circulation.—After this brief outline of the course which the blood takes through the circulatory organs in man and warm-blooded animals, it may be proper to introduce an enumeration of those circumstances which are generally adduced as affording the most satisfactory "proofs of the circulation" or evidence that the blood pursues the paths above detailed.

As proofs of the circulation, besides those derived from the connection of the different orders of great vessels with the cavities of the heart to which they are respectively attached, may be mentioned—

1st. The structure and disposition of the auriculo-ventricular valves of the heart, and semilunar valves of the aorta and pulmonary artery, which admit of the passage of blood from the auricles to the ventricles, and from the latter cavities to the great arteries, but not in a reverse direction.

2nd. The mechanism of the valves of the systemic veins which allow of the motion of fluid only in the direction towards the heart.

3rd. The fact that when a ligature is applied to an artery, or any other impediment opposed to the free passage of blood through it, the vessel becomes dilated on the side next the heart, while the application of a ligature to the trunk of a vein is followed by a turgescence of the vessel beyond the place where the obstruction occurs.

4th. That on opening one of the larger arteries, blood issues in a jet from the end next to the heart at the time of every contraction of that organ, and that in general no blood flows from the orifice of the remote part of the artery: and that on opening a vein the converse is observed, the blood issuing freely in a continued stream from the remote part, but none proceeding from the part of the vein adjoining the heart.

5th. That the passage of the blood from the arteries to the veins in the small or capillary vessels has been observed by means of the microscope in transparent parts of animals, and, though it has not been seen in man, we are entitled from the general analogy in the structure of the organs of circulation to infer that the same passage occurs in the human body.

6th. That, by mechanical arrangements, fluids may easily be made to pass in the dead body through the whole course of the double circulation, but not in a direction different from that which the blood has been stated to pursue.

7th. That by the operation of transfusion, the blood of one animal may be made to circulate through the heart and vessels of another, by connecting together the bloodvessels (whether arteries or veins) of the two animals, in such a manner that the course in which the blood is directed by the action of the heart of the animal from which the blood is derived is that of the natural circulation in the animal into which it is introduced.

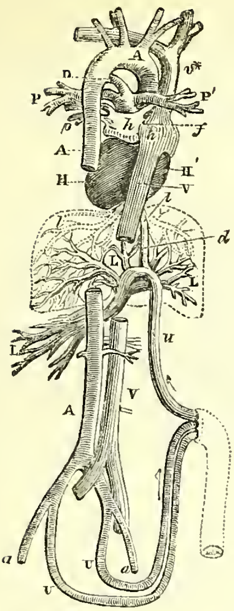
8th. The phenomena presented by the circulation of the blood in various diseased conditions of the heart and bloodvessels may be adduced as affording additional illustration of the natural course of the blood, by pointing out the effect of morbid obstructions and other varieties in different parts of the circulatory organs.

Course of the blood in the fœtus before birth.—The double circulation just described is the course performed by the blood from the time of birth during the whole of life.

The circulation of the blood, however, begins at a very early period of fœtal life; but the difference in the mode in which respiration is effected in the child so long as it is contained in the uterus, induces a modification in the course of the blood to which we shall now advert.

There being no inhalation of air into the lungs of the fœtus, the blood is sent only in small quantity to these organs, and does not undergo in them any change of properties. A considerable portion of the blood of the fœtus passes out of its body through the umbilical cord (*fig.* 313, U, u) into the placenta of the uterus. The minutely divided fœtal vessels are bathed by the blood of the mother contained in the placental sinuses, and, though no direct

Fig. 313.



Fœtal circulation seen from behind.

continuity of tube exists between the maternal and fœtal vessels, the blood of the child seems to undergo a respiratory alteration, or a certain degree of arterialization, in being brought into near proximity with the maternal blood.

The blood of the fœtus, after passing through the minute ramifications of the umbilical arteries *(U', U)* in the placenta, returns by the umbilical vein (*u*) into its body.

The umbilical vein carries part of its blood directly by the ductus venosus (*d*) to the vena cava inferior, and part is distributed by the branches of the vena portæ *(L)*, with which the umbilical vein unites, through the substance of the liver, and is then conveyed by means of the hepatic veins (*l*) into the general current of the returning blood.

The right auricle of the heart (*h'*), therefore, receives not only the blood which has circulated through the body of the fœtus, but also that which has passed through the placenta, consequently a mixture of venous and arterial blood;—the blood in the superior vena cava (*v**) being entirely venous, that in the inferior vena cava *(V)* being mixed. The blood which is brought to the right auricle is in much greater quantity in the fœtus before birth than in the child which has breathed air; a part of this blood passes from the right into the left auricle (*h*) by the foramen ovale (*f*) in the septum auricularum, and it would appear that it is chiefly the blood from the inferior vena cava which takes that course.

The rest of the blood entering the right auricle takes the same route as in the adult, viz. into the right ventricle *(H')*, and thence into the pulmonary artery, but, as very little blood is sent to the collapsed lungs, a passage of communication is established in the fœtus from the pulmonary artery into the descending aorta through the ductus arteriosus *(D)*, and thus the greater mass of the blood, which in the adult would have proceeded to the lungs, is in the fœtus immediately transmitted to the aorta *(A)*.

From the disposition of the Eustachian valve, it is believed that nearly the whole of the blood of the inferior vena cava passes from the right to the left auricle through the foramen ovale, while the blood brought from the head and superior extremities (parts which are comparatively large in the fœtal condition) passes through the right side of the heart. The ascending aorta, rising from the left ventricle, delivers almost all the blood expelled by the contraction of that cavity into the carotid and subclavian arteries, while the ductus arteriosus passing between the trunk of the pulmonary artery and the descending aorta directs the blood which passes through the right ventricle to the lower regions of the body. In this manner the upper regions of the body are supplied with the most arterialized part of the blood from the left side of the heart and aorta, while the purely venous blood is propelled from the right ventricle through the pulmonary artery and ductus arteriosus into the descending aorta, and consequently into the lower part of the body, and by the umbilical vessels to the placenta.

The foramen ovale in the septum of the auricles, the ductus arteriosus passing from the pulmonary artery to the aorta, the ductus venosus leading from the umbilical vein to the vena cava inferior, and the umbilical vein and arteries are the structural peculiarities of the fœtal circulating organs. These passages are all closed up, and the umbilical vessels obliterated at the navel after aerial or pulmonic respiration is established at birth.*

II. Course of the blood in various animals.

We now leave for the present the history of the circulation in man, in order to give a brief sketch of the varieties of this function in other animals, the study of which is calculated to throw considerable light upon some of the processes of the human economy, and to illustrate the anatomical and physiological relations of the circulatory and respiratory organs.†

It has been shewn that a regular and progressive circulation of the nutritive fluids occurs in those animals only in which the aeration of the blood is performed by a separate and dis-

* Sabatier, Mém. de l'Acad. An 8. Kilian, Kreislauf im Kinde, &c. Karlshruhe, 1826. Burdach's Physiologie, &c. vol. ii. Jeffray, Peculiarities of the Fœtal Circulation. Glasgow, 1834.

† In the following view of the comparative physiology of the circulation, besides the different works referred to under the separate heads, we have been guided chiefly by the following, viz. the works of Cuvier, Home, Meckel, Blumenbach, Treviranus, Carus, and R. Wagner; Roget's Bridgewater Treatise, and the excellent chapter upon this subject by J. Müller in Burdach's Physiologie, vol. iv. and in his Handbuch der Physiologie, vol. i.

tinct respiratory apparatus; and that, amid the immense varieties of form which the circulatory organs present in different animals, the course of the blood bears a more close relation in all to the form of their respiratory apparatus than to any other part of their organization. This general law of the relation between circulation and respiration, satisfactorily established by the extended researches of modern comparative anatomists, receives farther confirmation from many facts connected with the performance of these functions in the adult human body, and is illustrated in a peculiar manner by the remarkable changes which take place in the circulatory and respiratory organs of the child before and after birth.

In treating of the varieties in the course of the blood in different animals, we are at once freed from any embarrassment regarding the order proper to be pursued, by the circumstance that the form of the circulatory organs constitutes one of the principal bases upon which the modern classification of animals is founded; so that, in following the zoological arrangement, we take the order best adapted for our present purpose. As our object in giving this sketch is principally to illustrate the structure and functions of the human organs of circulation, we shall begin with the consideration of the course of the blood in those animals which most nearly resemble man; and trace the varieties in this function, as far as our knowledge permits, through the descending series of the animal chain.

1. *Course of the blood in warm-blooded animals.*—In Mammalia and Birds, the form of the organs of circulation and the course of the blood are essentially the same as in Man, for in all of these animals the heart contains four distinct cavities,—two auricles and two ventricles, and there is consequently a double circulation and a complete respiration.

Some considerable varieties in the form of the circulatory organs, which seem to have a relation to peculiarities in habits or mode of life, occur in certain mammiferous animals, such as the Cetacea, Amphibious Carnivora, the Sloths, Hybernating Animals, &c.; but we shall not at present enter upon the consideration of these varieties, because they do not amount to any deviation from the type or general plan of construction of the human organs of circulation, and consequently are not accompanied by any material difference in the course of the blood, but seem rather to have the effect merely of modifying the quantity of blood sent to particular organs, or of influencing its velocity and force.*

In the organs of circulation of the various tribes of Birds, we observe the same remarkable uniformity of structure which pervades the rest of their internal organization.

It may be remarked that, as in Birds a certain respiratory action takes place in the large air-cells distributed over the trunk of the body, and as the pulmonary vessels seem in most birds not to extend to these cells, but to be confined to the thoracic lungs, the blood contained in the small branches of the systemic arteries and veins, ramifying upon the lining membrane of the air-cells, must be made to undergo some respiratory alteration of its composition; but we have not as yet obtained the means of judging accurately of the extent to which such a respiratory change may be effected in the vessels of the systemic circulation, nor how far the minute branches of the pulmonary vessels may in some instances be prolonged from the lungs into the air-cells.*

Very frequent anastomoses take place among the veins of Birds. We may here mention one of these which induces an important modification in the portal circulation. By means of a communicating branch which passes from the united caudal, hemorrhoidal, and iliac veins to the vena portæ, the blood of the viscera of the abdomen and of the posterior part of the body may flow indifferently either into the vena cava inferior or the vena portæ, a disposition which may have for its object to prevent congestion of blood in the parts from which these veins proceed.†

A still more remarkable modification of the venous circulation in Birds was supposed to exist by Professor Jacobson of Copenhagen, consisting in the distribution of branches of the vena cava inferior to the interior of the kidneys and their subdivision in these organs, in the same manner as the vena portæ subdivides in the liver. Such veins transmitting venous blood to the kidneys, in the manner of a vena portæ, have been ascertained by Professor Jacobson,‡ and are admitted by others making subsequent researches, to exist in Reptiles and Fishes; but Nicolai§ has shewn that the lower veins, described by Jacobson in Birds as *venæ advehentes* of the kidney, do not differ from the other branches of the vena cava, and serve to carry away from these organs, like the superior renal veins of Birds and the renal veins of Quadrupeds, the venous blood derived from the arteries.

Course of the blood in cold-blooded vertebrated animals.—Of cold-blooded vertebrated animals, some, as the adult Batrachia, Chelonia, Ophidia, and Sauria, breathe air by means of lungs, while the rest, as the young Batrachia, the Protean, and Siren-like Reptiles and Fishes, are constant inhabitants of water, and breathe the air contained in that medium by means of gills or branchiæ. Of the aquatic cold-blooded animals, Fishes breathe by gills only, while the aquatic Reptiles or Amphibia are furnished with lungs as well as gills during the greater part of their aquatic life.

* See p. 678.

* See the article Aves, p. 330.

† It is a remarkable fact that there have been found, between the hemorrhoidal veins in Man and some branches of the vena portæ, anastomoses by small branches, which correspond in some respects with the disposition of the veins referred to above. These anastomoses were known to Haller, and are lately described by Retzius. See his Researches in Tiedemann's and Treviranus' Zeitschrift, vol. v. 1.

‡ Meckel's Archiv. vol. iii. p. 147. Edin. Med. and Surg. Journ. vol. xix. p. 78.

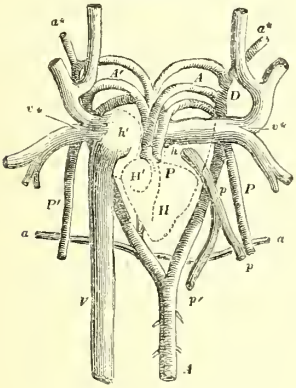
§ Isis, 1826, p. 414.

Reptiles.—The structure and functions of the circulatory organs in Reptiles form a subject of great interest on account of the numerous varieties which they exhibit in different orders and genera, for in this respect the class of Reptiles may be said to present to us an anatomical analysis of the circulatory and respiratory organs, and to constitute a gradually simplifying series of forms, the observation of which enables us to trace in the most clear and interesting manner an analogy and correspondence between the forms of these organs in warm-blooded animals and in fishes, which, but for the study of their structure in reptiles, must very probably ever have remained hidden from our view.

In Fishes the heart consists of one auricle and one ventricle, and a single current of blood only passes through it. The structure of the heart is very similar in some of the Batrachia breathing by gills, but among other reptiles, we find a gradual transition in the form and structure of the heart from that just mentioned as peculiar to animals with aquatic respiration, to the double heart possessed by warm-blooded and air-breathing animals.

Among the Reptiles provided with lungs and breathing air, some, as the Sauria, Ophidia, and Chelonia, have the ventricular part of the heart partially divided into two cavities (*fig.* 314,

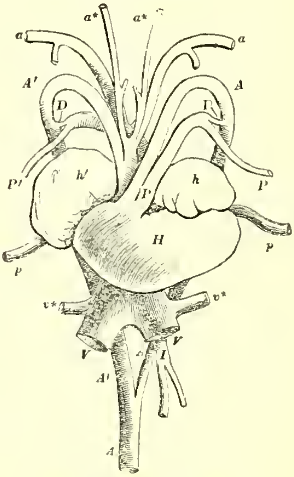
Fig. 314.



Heart of Lacerta ocellata.

H, H') which correspond in structure, relative situation, and connections to the right and left ventricles of the heart of warm-blooded vertebrata; the anterior or right compartment (*H'*) giving off chiefly the pulmonary (*P*), the left or posterior (*H*), the systemic arteries (*A*). In the others, viz. the Batrachia and Protean reptiles, the ventricle forms a single cavity (*figs.* 317 and 318, *H*), and gives origin to one large artery only (*A*), so that the pulmonary and systemic arteries derive their blood from the same trunk. In all of these, however, the auricle is double,* so that the venous blood from the system and the arterial blood from the lungs are received into separate auricular compartments of the heart, and are subsequently mingled together in the common ventricular cavity. In the Heart of the Crocodile of the Nile, Cuvier* has described three compartments, one of which corresponds to the left, the other two to the right ventricle, the septum between the right and left sides being incomplete. The heart of the Crocodilus Lucius is described by Hentz, Meckel,† and others as consisting of two ventricles, between which the septum is quite complete, so as to permit of no direct passage of fluid from one side to the other, possessing therefore in this respect, the same structure as the heart of warm-blooded animals. In those of the above-mentioned reptiles in which the septum is so nearly complete as to divide the ventricle into two separate compartments communicating by a small orifice, the arterial and venous blood are believed to be kept separate from one another by a valvular apparatus. Among the rest of the Saurian, Ophidian, and Chelonian Reptiles, in

Fig. 315.



Heart of Common Tortoise.

all of which the septum of the ventricular part is less complete than in the Crocodile, there is considerable variety in the extent to which the division of the cavity is effected by the septum. In a few of them the septum projects so little into the ventricular cavity that it cannot be supposed to divide to any extent, or to prevent the complete mixture of the two kinds of blood propelled from the opposite auricles.

In the Crocodile, and in those Reptiles in which the ventricular septum is nearly complete, the circulation, so far as regards the heart at least, may be considered as almost double, or the same as in warm-blooded ani-

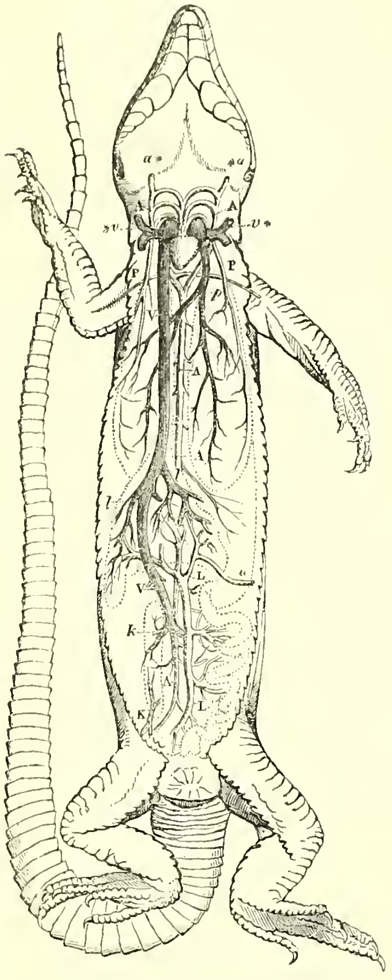
* The auricle of the Batrachia was generally described as single until the discovery of the left or pulmonary auricle in the Frog and Toad by Dr. John Davy. Mr. Owen has shewn this to be the case also in the Newt and Protean Reptiles; Zool. Trans, 1834, p. 213. See also Martin St. Ange's Plate of the Circulation, and M. Weber, Beitr. zur Anat. und Physiol. Bonn, 1832.

* Leçons, vol. iv. p. 221.

† Vergleich. Anatomie, vol. v. p. 231.

mals, that is to say, the arterial blood returning from the lungs to the left auricle *(fig.* 314, *h)* is directed entirely into the arteries of the system *(A)* from the left compartment of the ventricle *(H)*, and the venous blood brought back to the right auricle *(h')* by the venæ cavæ *(V v*)* is directed wholly into the pulmonary vessels *(P)* by the right ventricular compartment *(H')*.

Fig. 316.



Lacerta ocellata.

In all Reptiles, however, the descending aorta is formed by the union of two branches, the right and left aortic arches *(figs.* 314, 315, 316, and 317, *A', A)*; the right corresponds with the systemic aorta of birds, and rises from the left ventricular compartment, the left arch joins the right on the back, and leads generally from the right ventricular cavity into the descending aorta. The arteries of the head and upper extremities *(fig.* 314, *a*)*, arising from the right aorta *(A')*, which corresponds with the aorta of birds, and is connected with the left ventricular compartment, are supplied with highly arterialized blood proceeding directly from the lungs. The left arch of the aorta *(A)*, being connected on the other hand with the right ventricular compartment *(H')*, obtains, like the pulmonary artery, venous blood from the right auricle; and consequently the common trunk of the aorta, formed by the union of the right and left aortic arches, must carry to the posterior parts of the body a mixture of arterial and venous blood.* It may be remarked, however, that in the Turtle and some Lizards the left aortic arch does not join the right upon the back until after it (the left) has given off the great cœliac or rather visceral artery, which supplies the whole of the alimentary canal and digestive organs with venous blood *(fig.* 315, *I)*. The left aorta is thus much diminished in size before it sends its comparatively small communicating branch to the right.† From this disposition of the parts, it is obvious that in these animals the abdominal viscera must receive the greater part of the venous blood brought from the right side of the heart by the left aortic arch, while the right aortic arch which gives the carotid, brachial, vertebral, intercostal, and other arteries must carry to the parts it supplies in the first part of its course nearly pure arterial blood, and, after it is joined by the left, blood which contains a small proportion only of the dark or venous kind. In the Turtle, some Lizards and Serpents again, the arterial and venous blood must be mixed in the ventricular cavity though partially divided; the two streams of blood propelled into the aortic and pulmonary vessels must therefore be nearly of the same kind, and thus a part only of the blood which is sent to the lungs is made to undergo a respiratory change. In some of the Chelonia, the existence of ductus arteriosi, leading from the pulmonary artery on each side into the arch of the aorta, insures a still more complete mixture of the arterial and venous blood.‡

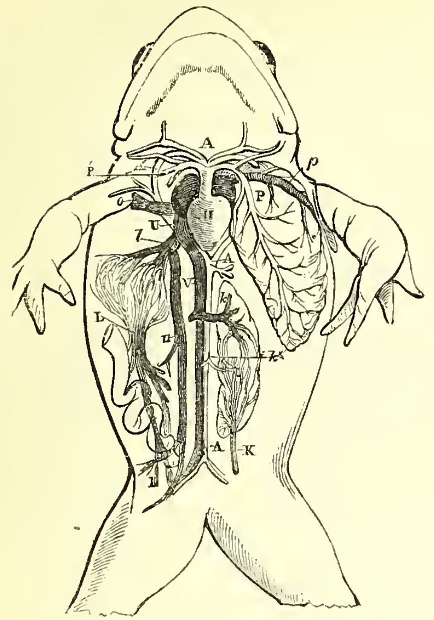
In most of the adult Batrachia the ventricle *(fig.* 317, *H)*, being single and giving rise to one arterial trunk only *(A)*, the pulmonary arteries *(P', P)* derive their blood from the great systemic aortic trunk of which they are branches; one coming off from each of the aortic arches which unite to form the descending aorta. The venous blood returning from the system *(V v*)* to the right auricle, is mixed in the common cavity of the ventricle with the arterial blood returning to the left auricle by the pulmonary veins *(p)*, and this mixed blood being propelled into the aortic bulb is distributed in part to the system and in part to the lungs. In these animals then, only a small quantity of a mixed blood is exposed to the action of the air in the lungs, which, from the simplicity of their structure, offer only a con-

* In the Crocodile, the left branch coming from the right ventricle is small and very short.

† See Bojanus' beautiful Anat. Monography of the Tortoise.

‡ In this respect, as well as in the mode of origin of the left aortic arch, the Tortoise and Turtle differ from one another.

Fig. 317.

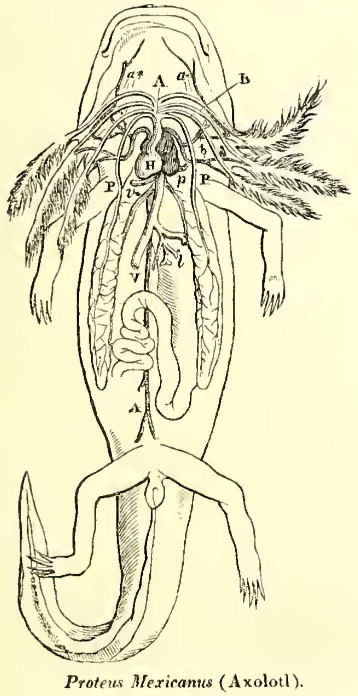


Frog.

fined surface for the distribution of the pulmonary capillary vessels.

In the aquatic Reptiles having gills, such as the larvæ of the Frogs and Salamanders in their transitory conditions, and the Protean animals,

Fig. 318.



Proteus Mexicanus (Axolotl).

which are very similar to them, but do not undergo, so far as is known, any further metamorphoses, the branchial organs are formed by an extension or minute subdivision of branches of the aortic trunk, supported upon the arches of the hyoid bones. In all of these Reptiles, the ventricle consists of a single cavity (*fig.* 318, *H*), which propels its blood into the bulb or commencement of the aortic trunk (*A*). The aortic trunk divides into two branches, each of which subdivides again into three or four vessels upon each side of the neck. These vessels (*B*), passing round the gullet or upper part of the alimentary canal in the form of lateral arches, unite again together behind, to form the descending aorta. The branchial apparatus of the animals now under consideration is formed entirely upon these lateral arches of the aortic trunk. In the larva of the Salamanders, in the Proteus, Axolotl, Menobranchus, and Siren,* the small branches of each gill are formed by the minute subdivision of a loop of vessel prolonged from the outer part of three of the arches on each side into leafed processes of the cuticular system attached to the hyoid arches (*B*, *b*).

The larva of the Frog has, in the earliest stage of its existence, gills of the same kind as those just described; but in its more advanced condition these external gills disappear, and the larva of the frog breathes by internal gills more resembling those of fishes than the external branchiæ of the Newt or Proteus. The gills of the tadpole of the Frog are covered by the skin, and consist of a great number of small leaflets, receiving the minutely subdivided loops of vessel given off for some way along each of the four vascular arches as they pass round the neck along the cartilaginous hoops of the hyoid bone. The vascular arches are double in that part of their course where they are connected with the gill, the blood being transmitted from one branch to the other in passing through the leaflets of the gill.

In the larvæ of the Batrachia, from a very early period of their existence, as well as in the Protean Reptiles, there are lungs which seem to be used as adjuvant respiratory organs, for they are generally filled by the animal with air from time to time. These lungs, more or less perfectly developed in different kinds of Protean Reptiles, and at different stages of the existence of the Batrachian larvæ, all receive a pulmonary vessel from the vascular arch of the aorta which is nearest the heart, whether this arch is connected with a branchial apparatus or not.

In all these animals the anatomical relations and the mode of development of the blood-vessels of the gills proves distinctly their returning vessels to be, as much as those which conduct the blood into them, branches of the arterial system; but the lungs on the other hand, however rudimentary, are almost always furnished with proper pulmonary veins which lead to the auricle of the heart.

The following is the course which the blood takes in this interesting class of animals. The

* We omit the consideration of the Amphiuma, Menopoma, and Cœcilia.

heart (h, H) receives the whole venous blood of the body by the right auricle, and a small quantity of arterial blood from the lungs by the left. These two kinds of blood, mixed together in the common ventricle, proceed from thence into the aortic bulb and its branches (A, B, b). In the larva of the Salamander and Protean Reptiles, a part of the blood is sent by pulmonary vessels to the lungs, from which it is returned by the pulmonary veins to the heart; a part passes directly round the arches, and gains the descending aorta; the greatest quantity passes out into the gills, and after being arterialized returns to be mixed with that in the aorta, so that a mixed blood must permeate all the vessels of the systemic circulation. In the Siren, according to Cuvier and Owen, the whole blood goes at once to the gills, from the want of any communicating twigs across the root of these organs. It is interesting to remark that the arteries of the head and upper extremities (a) are not given off by the aortic arches until after they are joined by the returning branchial vessels, a disposition which is in some respect similar to what we find in higher Reptiles, and which seems to have for its object the supply of a more pure arterial blood to the cerebral organ.

In the larva of the Frog, the course of the blood is very similar to that of Fishes. The whole of the venous blood propelled through the heart is sent into the gills, and is made to pass through them before reaching any other part. From the posterior parts of the first arches are given off the vessels of the head, the second form the right and left roots of the descending aorta, and the fourth are continued upon the lungs in the form of a pulmonary artery. There is however also in the larva of the Frog a short anastomosis between the outgoing and returning artery of each of the gills, which allows of a direct passage of some blood round the arches of the aorta.

In the Protean Reptiles and larva of the Batrachia a greater quantity of blood is sent to the respiratory organ than occurs in the adult Frog or Salamander.

Portal circulation in Reptiles.—In the class of Reptiles there are two lesser venous circulations besides those already described; the one, similar to the portal circulation of warm-blooded animals, belongs to the liver; the other, which does not appear to occur either in Birds or Mammalia, belongs to the kidneys. According to Jacobson, who was the first to point out the existence of veins carrying blood to the kidneys in the Amphibia, and the later researches of Nicolai and others, there are two principal vessels which carry back blood from the posterior parts of the body, viz. the anterior abdominal, and the inferior renal veins. These two vessels are formed by the union of the iliac, caudal, posterior cutaneous, pelvic, visceral, abdominal, and umbilical veins; and in most Reptiles, excepting the Ophidia, the renal and portal vessels proceeding from the posterior parts of the body arise together. In some Reptiles the whole of the blood returning from the posterior parts of the body is divided between the portal veins of the liver, and the venæ advehentes of the kidney; in others a part is also sent into the abdominal vena cava. The inferior renal or advehent veins of the kidneys (*figs.* 316, 317, and 318, K) carry venous blood to these organs, and distribute it minutely through their substance. It is removed from thence and returned into the great circulation by the revehent or superior renal veins (k) which lead into the vena cava.* The anterior abdominal vein (*fig.* 316, u) is the same to which Bojanus has given the name of umbilical in the Tortoise, in which class of animals it is of very large dimensions, and receives not only the venous blood from the posterior extremities and shell, but also some from the anterior extremities. The persistence of those umbilical veins which proceed from the large urinary bladder in many of the adult reptiles is a fact of some interest, because it points out a resemblance between the permanent distribution of the vessels in these reptiles and the fœtal condition which we find in the higher animals, and likens the bladder of the scaly Reptiles, as well as of the Batrachia in which during fœtal life no allantoid membrane is ever formed, rather to an allantoid receptacle than to a proper urinary bladder.

Fishes.—In fishes there is no vestige of a pulmonary organ, and the respiration is wholly effected by means of the gills. The branchial apparatus of fishes is internal or covered, like that of the larva of the frog; it is placed on the cervical part of the alimentary canal, and is formed by the fine subdivisions of aortic arches (*fig.* 319, A, B, b), which are prolonged into the fringed or leafy processes of the hyoid branchial arches. The respiratory organ is thus placed in this class in the course of the arterial circulation. The venous blood from the body generally, and from the liver, enters the single auricle (h) through the great sinus (V), and is wholly propelled into the arterial bulb by (A) the single ventricular cavity (H). No systemic arteries come from the aortic bulb, but this vessel carries by the arches into which it divides (B), the whole of the venous blood into the gills. The number of these arches subdividing and ramifying in the gills varies in different fishes. In a few, as the Lophius, there are only three on each side. In most osseous fishes there are four. In the Skates and Sharks there are five. In the Lampreys there is the greatest number known, namely, six or seven.

The blood, after having undergone arterialization in the gills, is not returned to the heart, but proceeds directly through the branches of the aorta (*fig.* 319*, b b, A) to different organs. The force of the heart acts therefore through the whole of the capillary system of the gills (bc), and continues to propel the arterialized blood

* It must be remarked that Meckel, who appears to have examined the distribution of the above mentioned vessels with great care, denies entirely the advehent function of the lower veins of the kidneys both in fishes and reptiles, considering all the veins of the kidney as revehent. Vergleich. Anat. B.V. S. 201 and 253.

Fig. 319.

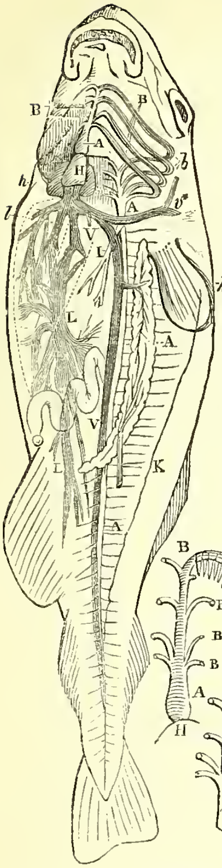
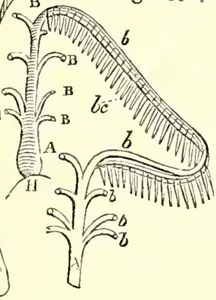


Fig. 319*.



Fish.

through the branches of the aorta (*A*) in the various parts of the systemic circulation. Dr. Marshall Hall* and J. Müller† have observed a dilated contractile part of the caudal vein in the tail of the Eel, to which Dr. Hall has applied the name of caudal heart, which may assist in promoting the flow of blood in the caudal branches of the vena cava.

The position and anatomical relation of the heart of fishes with the bloodvessels as well as other parts shew that it corresponds to the whole heart of higher animals, and that the arterial vessel which receives the whole of the fish's blood from the ventricle may strictly be considered as the commencement of an aorta entirely destitute of any pulmonary branches. Although there is no distinct right ventricle to propel the blood to a pulmonary organ, and the whole of the blood issuing from the heart is sent directly to the gills, there is not on this account any sufficient reason for considering, as some have done, the heart of the fish as corresponding to the pulmonary or right cavities of the heart in warm-blooded animals, for we have seen that in some of the reptiles when they have gills, the blood is driven into these organs through the aorta or systemic trunk. The branchial arteries in fishes, as in reptiles, are therefore branches of the great aortic trunk, and the returning vessels on the posterior side of the arches, or branchial veins as they are called, are as much of an arterial nature both in their structure and relations as the anterior vessels or branchial arteries are. When these returning vessels unite together on the back to form the descending aorta, it is not necessary therefore to suppose them to undergo a change from the venous to the arterial structure. So far then as general structure and relative position are concerned, the heart of the fish corresponds to the whole heart of warm-blooded animals, and not to one or other set of its cavities. Nor does the contemplation of its function or uses in the circulation induce us to modify this view, for it is manifest that the heart of the fish, as it serves to propel the blood through the gills into the vessels of the system, and as the branchial vessels may be considered as belonging to the aortic system, acts at once as a branchial and a systemic heart.*

We have abstained from entering at this place into the detail of those remarkable changes formerly alluded to, which the circulatory and respiratory systems and the systemic and branchial or pulmonary circulations undergo during the development of the young of animals, although these afford the most direct proofs of the justness of the view now taken. Under the head of Ovum we shall have a more fitting opportunity of explaining these fully. Suffice it for the present to say that the heart of the highest warm-blooded animals passes, during the progress of its development at different periods or stages, through the same general outline of various forms which that organ retains permanently in the adults of fishes or different reptiles; and that the aortic arches and a semblance of a branchial apparatus connected with them is not confined to those animals which necessarily employ gills for a time as respiratory organs, but are to be found also in the fœtus of the scaly reptiles, birds, and mammalia in the early stages of their existence. The ductus arteriosus, double in birds and single in mammalia, is, we may remark, the last of those transitory structures which remains in the fœtus.

Portal circulation of fishes.—In fishes, as in reptiles, both the liver and kidneys have venous blood distributed to them by the subdivision within these organs of veins (*L* & *K*) from the abdominal viscera and posterior parts of the body. The vena portæ of the liver consists generally of veins from the stomach, intestinal canal, spleen, pancreas, and sometimes from the genital organs, swimming blad-

* Essay on the Circulation of the Blood, p. 170. Lond. 1831.

† Handbuch der Physiol. vol. i.

* Blainville, Sur la Degradation du Cœur, &c. Bull. de la Soc. Philomathique, 1818-19, p. 148.

der, and tail. There is, however, considerable variety in regard to the distribution of the posterior abdominal veins in fishes; and comparative anatomists do not appear as yet to have connected these varieties with any general view of their uses. In the Gadus the venous blood from the tail and middle of the abdomen goes to the kidneys only by venæ advehentes. In the Silurus the blood of the posterior parts of the body is carried to both the kidneys and liver; and in the carp, pike, and perch, to the kidneys, liver, and vena cava at once. The blood from the testicle, ovary, swimming bladder, and kidneys, most frequently goes to the vena cava.*

Course of the blood in Invertebrate Animals.—In investigating the course of the blood in animals destitute of a vertebral column and cerebro-spinal nervous system, we are no longer guided by any such analogies of form, position, and use, as those just attempted to be traced in the circulatory organs of the *Vertebrata;* for each class of Invertebrate animals, as Mollusca, Articulata, and Zoophyta, and even their subordinate orders, differ so widely from one another in their organization, that we are at a loss to discover any general plan or type to which their circulatory organs may be referred.

In all of the Invertebrate animals in which there is a regular progressive motion of the nutritive fluids, there exists also a central contractile organ to which the name of heart is applied, from its functional rather than structural analogy to the central propelling organ of the circulation in Vertebrate animals; and in many of them, the outgoing and returning vessels in which the circulation is performed may be distinguished into arteries and veins, by a difference of structure as well as of office. From the same kind of analogy, the name of auricle is given to the weaker part of the heart of Invertebrate animals, which serves to receive the returning blood from the veins, when such a cavity exists, and we call ventricle the stronger and more muscular part which propels the blood into the arteries. The general form of these parts, however, and their position relatively to the other systems, render it extremely difficult, if not altogether impossible, to trace any strict anatomical correspondence between the heart and bloodvessels of Vertebrate and Invertebrate animals. In the Invertebrate animals, the heart and principal artery are generally placed on the upper part of the body, above the alimentary canal and largest portions of the nervous system; while in all Vertebrate animals the order is reversed, the brain and spinal marrow being above, the heart below the alimentary canal.

In the *Invertebrata*, as in the higher animals, the respiratory change of the blood is the most important function to which its course or circulation bears a constant relation. In the *Vertebrata* the blood flows from the heart to the respiratory organ, while in the Invertebrata the blood very generally arrives at the heart after having passed through the respiratory organ, and is propelled from the heart into the systemic circulation: the vessels, therefore, in which respiration is effected in the lower animals may be considered as belonging in general to the venous circulation only, while in the higher classes of animals, arteries alone, or arteries and veins together, conduct the blood through the respiratory organ. Another remarkable difference between the circulation of the nutritive fluids in Vertebrated animals and that in the Invertebrate classes consists in this, that in the first the digested food or chyle and the lymph are taken up by a system of vessels distinct from those circulating blood, and are poured into the venous circulation at one or more determinate places; while in the latter animals, the bloodvessels, so far at least as we yet know, perform the office of lacteal and lymphatic absorbent vessels as well as of circulatory organs. In the Invertebrate animals also, there is no vena portæ, as in the Vertebrata, and the liver is supplied with blood only by a hepatic artery.

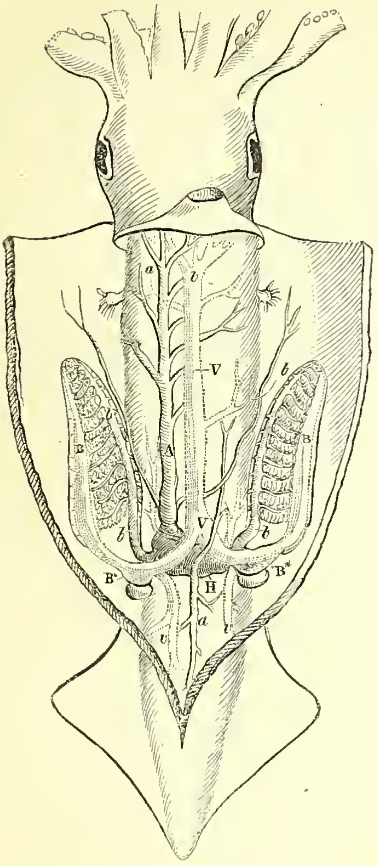
In investigating the structure of the circulatory organs in different classes of Invertebrate animals, we at once perceive that no accurate correspondence can be traced between the varieties of their forms and the places assigned to the animals in a Zoological arrangement; for we find among the Mollusca some tribes having a highly developed and complicated circulatory apparatus, and others with heart and bloodvessels comparatively simply organized. The same discrepancy occurs among the Crustacea, Annelida, and Insects; and among the Entozoa and some other tribes of Zoophytes, while some possess a simple circulatory apparatus, in others we are not able to discover any vestige of a vascular system.

There is a considerable number of the lower animals in which no vascular system has yet been discovered, and in which the nutritious juices are supposed to pass from the alimentary cavity by interstitial transudation through all the parts of their bodies. The circulation has, however, been recently shewn to exist in animals formerly believed to be without it, and the farther progress of Comparative Anatomy may diminish still more the number of animals believed to be destitute of circulating organs: in the present state of our knowledge, it is therefore as difficult to say with certainty in what animals this function is deficient, as it is to fix in which it is of the most simple or most complicated kind.

Mollusca.—The greater number of the Mollusca live in water and breathe by means of gills, but many aquatic Mollusca, possessing a branchial apparatus, appear to have their blood aerated in other parts of the body also. There is a strong muscular heart in all the animals belonging to this class, which when single is always systemic, (*figs.* 320, 321, and 322, *H.*) In the Cephalopoda, besides the aortic or systemic heart, which has only one cavity or ventricle, each vessel (*fig.* 320, *B*) leading to

* See the papers of Jacobson and Nicolai already referred to, and the extended Researches of Rathke, Meckel's Archiv, 1826, and Annal. des Sciences Nat. tom. ix.

Fig. 320.

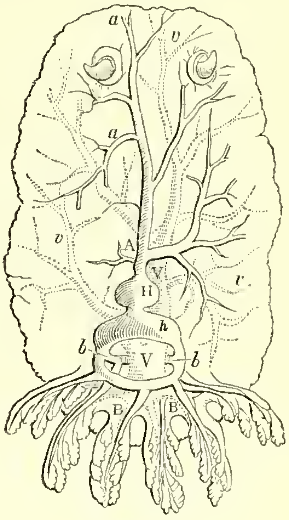


Cuttle-fish.

the gills has a dilated contractile portion (B^*), which dilatations may be considered as branchial hearts, so that there are three separate contractile portions of the circulatory system. In the Gasteropoda and Pteropoda, there is only one heart. This organ is strong and muscular, provided with valves, and consisting of an auricular and a ventricular cavity (*figs.* 321 and 322, *h, H*). In the Testaceous Acephala, the heart is nearly of the same structure as in the orders just mentioned, but less fully developed. In most of them, as also in the Gasteropodous Mollusca, the rectum passes through the ventricle. The auricle is occasionally double. The Brachiopoda have two aortic hearts, but of a very simple structure, not being divided into auricular and ventricular portions. The naked Acephala, such as the Ascidiæ, have the simplest heart of all the Mollusca, consisting of a thin membranous ventricle apparently without valves.

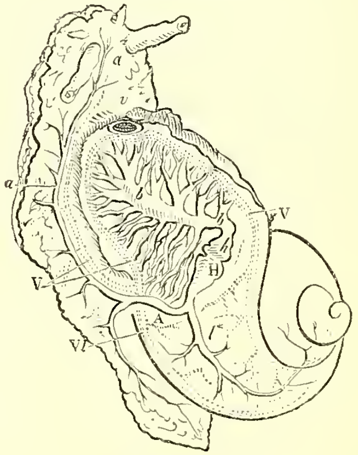
In all these animals, the course of the blood is generally considered to be the following: Arterial blood only passes through the systemic or aortic heart (or hearts where this organ is double), and is carried to the system by the branches of the systemic arteries (*A, a*). The altered blood, returning in the veins of the system, is collected into one or more trunks (*V*), and carried in the subdivided branches of these (*fig.* 321, *fig.* 322, *B*) to the re-

Fig. 321.



Doris.

Fig. 322.



Helix.

spiratory organ, which consists of branchial plates or fringes in the greater number, but in some of the Gasteropoda, as in the Garden-Snail, of pulmonary sacs. In most cases, the whole of the blood returning from the system passes through the respiratory organ. In others, especially in some Bivalves, the vena cava or systemic veins send branches directly to the auricle as well as to the gills.

In the compound Ascidiæ, Mr. Lister* has recently discovered one of the most remarkable modifications of the circulation with which we

* Philos. Trans. 1834, p. 378.

are acquainted. Mr. Lister finds that the different Ascidiæ of a branched animal are not only connected together by the polypiferous stem, but have a common circulation. In each individual there is a heart consisting of one cavity only, and pulsating about thirty or forty times in a minute. In the common stem, the motion of the globules of the blood indicates distinctly two currents running in opposite directions. One of the currents enters the Ascidia by its peduncle and proceeds directly to the heart; the blood issuing from the heart is propelled into the gills as well as the system at once, and upon its return from thence the returning current proceeds out of the animal by its peduncle again into the common stem, whence it goes to circulate through another of the ascidiæ attached to the stem. The directions of the currents appeared to be reversed every two minutes or less. According to Mr. Lister, when one of the ascidiæ is separated from the common stem, its circulation goes on in an independent manner; the blood returning from the body being conducted into the heart, but the alternation of the directions still continues,—a circumstance which points out an important difference between the compound and the simple ascidiæ, in which last the circulating fluid is generally believed to pass from the gills into the heart, and to hold continually the same direction.

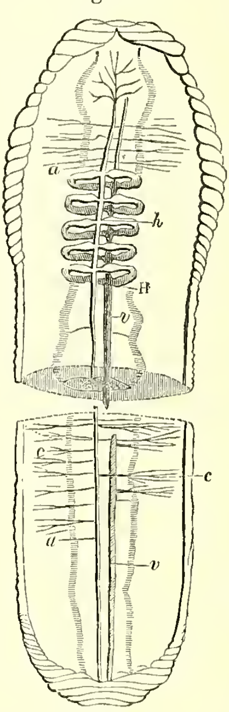
Articulata. — In this class of animals, varied as the forms of the circulatory organs appear, the position of their principal parts is much more constant than in the Molluscous animals. In some, as the Decapodous Crustacea, there is a short and thick muscular heart connected with the systemic arteries. In others, the contractile part of the vascular system is much more like a dilated artery than a circumscribed heart, as occurs in some other Crustacea, spiders, and insects; and in the Annelida the greater part of the large vessels seem to be endowed with a contractile power by which they propel the blood.

Annelida.—Although the Annelida form the highest division of the class Articulata in the arrangement of Cuvier, their circulatory organs may for the most part be regarded as more simple than those of most of the others. The circulation is best known in the Naides, the Leech, Earthworm, and Sandworm. In all of these, the blood, which is generally red, moves gradually forwards in the vessels situated on the upper surface of the animal, and backwards in the vessels placed below or on the abdominal side. There are also numerous cross vessels which transmit the blood from one side to another, or from above downwards, or from below upwards, in each of the compartments or joints of the animal. The upper vessels, being generally the most contractile, are considered as the arteries; the lower vessels as veins.*

The organs of circulation appear to be simplest in the Naides. In these animals, the contractile part or heart is represented by an artery above. This vessel turns round at the head into the vein which is below. The artery sends its blood partly into the gills, placed along the whole length of the body, from which it again receives the returning blood, and by numerous lateral branches, which may be regarded as the only capillary vessels, it sends blood across the body of the animal into the vein. The motion of the blood appears to be partly progressive and partly oscillatory.

Lumbricus. — In the common earthworm, there are two principal vessels, the one (*fig.* 323, *a*,) placed above and the other (*v*) below, and extending the whole length of the body; these two principal vessels communicate together by very numerous small cross branches (*c*), and, in the neighbourhood of the ovaries, by from five to eight very remarkable necklace-shaped or moniliform vessels (*h*, *H*). At the place of junction of these moniliform vessels with the lower longitudinal one, there are small dilatations of that vessel, which are believed to aid in propelling the blood by their contractions. There are also three other longitudinal vessels, much smaller than the principal or median ones, which join with the cross anastomosing twigs.

Fig. 323.



Lumbricus.

The upper principal vessel pulsates in an undulatory manner, the contraction taking place first at the posterior part, and proceeding gradually forwards. In these animals, however, the course of the blood does not appear to be very well known. It is believed to be from behind forwards in the upper vessel and from before backwards in the lower, but there must be also lateral motion. Both the upper and lower vessels are said to give off pulmonary branches.

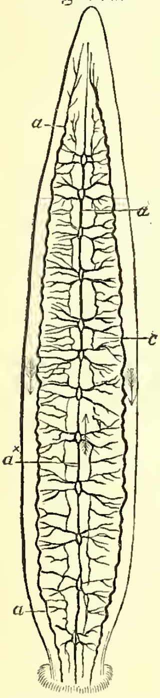
Arenicola.—In the sandworms also, besides the principal upper and lower vessels, there are two smaller ones, placed one on each side of the abdominal nervous cord, and two others upon the intestine; between these there is a very minute net-work of smaller branches. The branchial arteries are derived from the upper longitudinal vessel, the branchial veins lead into the lower. The greater part of the blood proceeds from the upper vessel into the gills by the branchial arte-

* See the article Annelida, p. 169.

ries; by the branchial veins it gains the lower vessel. This vessel may be regarded as the systemic artery, and sends the arterial blood, by the numerous anastomosing branches, upwards across the intestine, and through the other parts into the upper vessel. The upper vessel communicates also with the lower anteriorly by the lateral dilatations named auricles, which are supposed to furnish some blood to the upper vessel. A part of the blood at the anterior extremity of the lower vessel is said to be propelled into the two subordinate vessels placed along the sides of the nervous cord. In this course which the blood is stated to follow, it does not appear to be known whether its motion is of a regular progressive kind or only undulatory.

Leech.—In the leech the principal and most highly contractile longitudinal vessels are placed one on each side (*fig.* 324, *a, a*), and there are also two lesser longitudinal vessels, one superior and the other inferior (a^*), all which communicate freely together by small cross branches along the whole body (*c*). It is remarkable that the lower median vessel (a^*) incloses the ganglionic nervous cord, so as to bathe it with blood. Both pulmonary arteries and veins are branches of the lateral vessels; a capillary network between them distributing the blood minutely over the pulmonary sacs or vesicles. The pulmonary veins form very remarkable dilated and coiled portions, which seem to be endowed with a high degree of contractility. According to J. Müller, for a certain number of pulsations, the middle and the lateral vessel of one side contract together, and propel the blood into the lateral vessel on the other side, and then the order is reversed, and the middle vessel acts along with the lateral vessel of the other side, so that one lateral vessel is always dilated while the median and opposite lateral ones are contracted, and vice versa. According to some there is thus only an alternate motion of the blood from one side to the other, while others believe that there is at the same time a gradual progressive motion of the blood forwards in the upper vessel and backwards in the lower one.*

Fig. 324.



Erpobdella or Leech.

The course of the blood in the principal parts of the circulatory organs is nearly the same in the rest of the Articulata, viz. Crustacea, Arachnida, and Insects, as in Annelida. In all of them the central propelling organ, whether in the form of a heart or consisting only of a dilated arterial vessel, such as the dorsal vessel of insects, is situated on the upper surface of the animal, above the alimentary canal, while the returning vessels are situated on the lower surface of the body, on each side of the nervous ganglionic cord. The respiratory circulation, when occurring in a distinct set of vessels, forms a part of the venous system, and the heart, which has no auricle, is systemic or aortic.

Insects.—All perfect Insects, whether inhabitants of air or water, breathe air alone. In these animals there is not a separate and distinct respiratory organ in one part of the body only, but the atmospheric air is carried by minute elastic and tough tubes ramified to an infinite degree of minuteness into every part of their body.

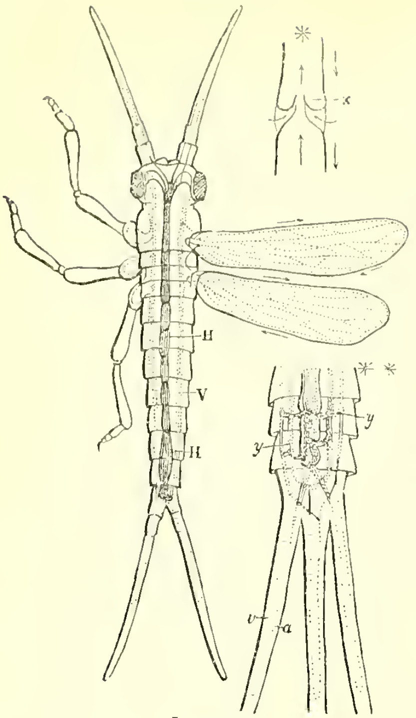
The dorsal vessel of insects forms a long and wide contractile artery, larger in general behind than before, in which the contractions begin at the posterior extremity, and proceed gradually forwards with an undulatory motion. In the greater number of perfect insects, we are not acquainted with any other vessels or passages in the body, through which the blood moves, and this fluid seems in these insects to oscillate backwards and forwards in the dorsal vessel alone. This state of the circulation in insects, according to the ingenious views of Cuvier, is related to the distribution of the respiratory organ over the whole body, in consequence of which the air is brought in contact with the more perfect blood contained in the dorsal vessel, and the nutritious fluids supposed to pervade interstitially the rest of the body. The recent discovery by Carus of a continuous circulation of the blood through arteries and veins in a few of the perfect insects, and more especially in some larvæ, must modify the above views, which, ingenious as they must appear to all, do not account so satisfactorily for the absence of a systemic as for the want of a pulmonary circulation. The circulation of the blood of Insects may be most easily seen in the aquatic larvæ of Neuropterous Insects, as the Agrion, Ephemera, Semblis, and Libellula,* in which it was first discovered.

In these larvæ it may be described generally as follows. The dorsal vessel (*fig.* 325, *H*) is connected anteriorly and posteriorly by several branches with the inferior or returning vessels (*v, v*), which, running along the whole body, receive the blood from the anterior extremity, and carry it into the posterior extremity of the dorsal vessel. The antennæ and first joint of the legs, as well as the fin-shaped caudal processes, receive each a loop of vessel from the abdominal current; and from the motion of the globules in these transparent parts, the circulation can be more easily seen in them than in

* See a full account of most of the opinions of observers on this subject, as well as original observations by Rudolf Wagner, in the Isis for 1832, p. 643.

* We have ourselves seen the circulation in the larvæ of two Neuropterous Insects.

Fig. 325.



Insects.

any other parts (*fig.* 325 **, *a, v*). A network of vessels is also distributed over the surface of the imperfectly formed wings. As the metamorphosis from the larval to the perfect state advances, and shortly after the insect leaves the water to assume the aerial condition, the circulation of the blood becomes gradually confined to a more and more circumscribed space. The loops extending into the wings, limbs, caudal processes, and antennæ, become shorter; when the metamorphosis is complete, they become entirely closed, and in general this change is followed by the disappearance of the inferior lateral or returning currents also. These remarkable changes in the circulatory organs at once indicate an interesting relation of their condition to the changes in the mode of life of the insect. In the aquatic state, the caudal and lateral laminæ, antennæ, and wings may be considered as serving the purposes of gills, for the blood is carried to them, and exposed upon their surfaces to the action of the water. The larvæ of the neuropterous insects generally feed largely, but their life during the perfect condition, when the circulation has ceased, is of short duration, and they either take very little food, or live in absolute abstinence. It has been also shewn that the dorsal vessel consists of different compartments, between each of which a valvular apparatus (*fig.* 325*, *x*) prevents the passage of the blood in a retrograde direction. There are lateral openings in the neighbourhood of the valves, by which it would appear that the blood is admitted into the dorsal vessel from cross branches (*fig.* 325 **, *y*) passing directly from the lateral streams. It may be mentioned that the larger returning streams of blood, situated on the lower side of the body, are said by Carus and Wagner, we cannot judge with what reason, not to be inclosed within vascular parietes, but to run loose in the texture of the insect. A complete circulation is not, however, confined to the larvæ of insects, having been discovered by Carus and others in some of the perfect insects. Carus saw it in the wings of the Semblis developed for flight. The circulation has also been seen by Carus in the larvæ of Water-beetles, Hydrophilus, and Dytiscus, and by Ehrenberg and Hemprich in the Mantis, so that the circulation has now been discovered in insects belonging to four orders, viz. Coleoptera, Diptera, Orthoptera, and Neuroptera.

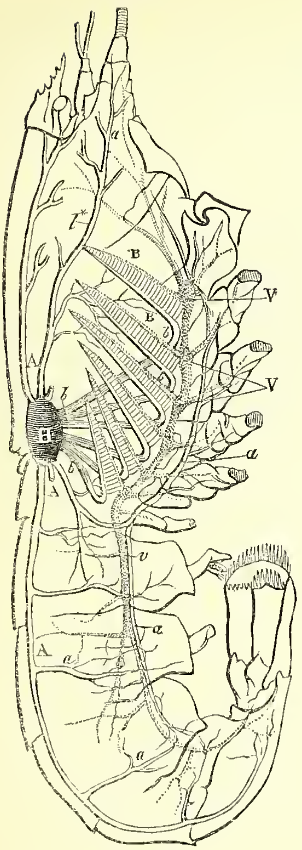
Crustacea.—In the Stomapoda, Isopoda, and Branchiopoda, or in the Squill, Oniscus, and Monoculus or Daphnia, the circulation is generally described as being of the same simple kind as that just stated to occur in the larva of insects, with this exception, that the blood is carried to gills for the purpose of undergoing a respiratory change. In most of them the venous blood which is sent to the gills comes directly from the systemic veins. From the description given by Gruithuisen of the circulation in the Daphnia,* it would appear, if his observations are correct, that the venous blood is sent to the heart before going to the gills,—a distribution very dissimilar from that which exists in the rest of the articulated animals. In this animal, Gruithuisen also describes an auricle and ventricle in the heart.

The investigations of Messrs. Audouin and Milne Edwards have pointed out very clearly the structure of the circulatory organs and the course of the blood in the larger Decapodous and some other Crustacea. The aortic heart (*fig.* 326, *H*), consisting of a single ventricular cavity, and situated below the posterior margin of the thoracic shield, gives off six systemic arteries (*A, a*), which convey the arterial blood to the various organs of the body and to the liver (*l**). The venous blood, returning thence in the systemic veins (*v, v*), is collected on the lower surface of the body into sinuses (*V, V*), from which the branchial arteries (*B*) take their origin; the branchial veins (*b*) return the blood which has passed through the gills to the heart.

Arachnida.—In those of the Arachnida in which the respiratory organ consists of tracheæ like that of insects, the circulation has been supposed to be much the same as in these latter animals. The dorsal vessel, however, approaches to the form of a heart posteriorly, being there more dilated at one part than in the rest of its course, and considerable lateral vessels are known to be given off from it upon either side. In others of the spiders, in which the respiratory organ consists of pulmonary cavities admitting air, it is conjectured that the blood is distributed on the surface of the plates

* Nova Acta Nat. Cur. xiv. p. 404.

Fig. 326.



Lobster.

within these sacs, as upon the gills or lungs of other animals, but the exact course of the blood does not appear as yet to have been satisfactorily ascertained in these animals. Audouin* believes it to be essentially the same as in the Crustacea. The long-shaped dorsal vessel or heart gives off arteries to both sides, and receives at one place branches from the gills. The veins form only spaces or sinuses, and not vessels on the abdominal side of the animal. The blood propelled from the artery is passed through the system, returning from which, it is collected into the venous sinuses below, thence it proceeds to the pulmonary organs, and after passing through them, returns to the heart.

Zoophytes.—The general character of the circulation in this class is exceedingly obscure; for while in some of the animals belonging to it, comparative anatomists have not succeeded as yet in pointing out any distinct vascular system; in others, they have been at a loss to determine, among various vascular organs, which of them forms the proper circulatory system corresponding with that of higher animals.

Echinodermata.—Among the Zoophytes the Echinodermata present the most fully developed vascular system with which we are acquainted. According to the observations of Tiedemann and Delle Chiaje, who have investigated the structure of these animals with great success, there are two principal divisions of the vascular system, described by the first of the above-mentioned authors as distinct from one another, by the other as communicating together.

We do not feel inclined to consider, in accordance with the view of these authors, that series of cavities which is employed in locomotion as a part of the nutritive circulatory organs.

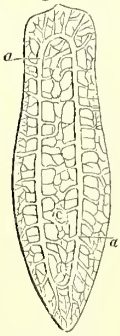
That part of the vascular system of these animals again, which is situated in the neighbourhood of the alimentary canal, very probably corresponds with the circulatory organs which we have been describing in other animals; since arteries and veins can be distinguished in it, and there is good reason to believe that a circulation of fluid takes place through its vessels in all the kinds of Echinodermatous animals.

In the Holothuria, the principal artery or heart is connected with a ring situated round the commencement of the alimentary canal, from which the systemic arteries are given off: the systemic veins send branches to the gills, and the returning vessels from these organs transmit the circulating fluid through one large trunk into the heart.

The intestinal vascular system of the Asterias and Echinus is somewhat similar to that of the Holothuria, consisting of annular vessels, from which arteries and veins are given off, and connected with a dilated contractile canal, considered as a heart.

Planaria.—Next to the Echinodermata in respect of the degree of perfection of their circulatory organs, may be mentioned the Planariæ, in which M. Duges* has pointed out a very remarkable system of vessels which appear to constitute circulatory organs (*fig.* 327, *a*, *a*). For some time previously to the discovery of these vessels, the singularly branched intestinal cavity of the Planaria and some Entozoa was believed to hold the place of organs of circulation, the same cavity in which digestion occurs being believed to carry by its ramifications the nutritious fluids to different parts of the body. But Duges has shewn the existence in them of a system of vascular organs resembling considerably those of the Leech, to which animals the Planaria bears, in other parts of its organization also, a striking analogy. The vascular system of the Planaria consists of three principal longitudinal trunks, two lateral and one dorsal or median, which are all united together by numerous minute anasto-

Fig. 327.



Planaria.

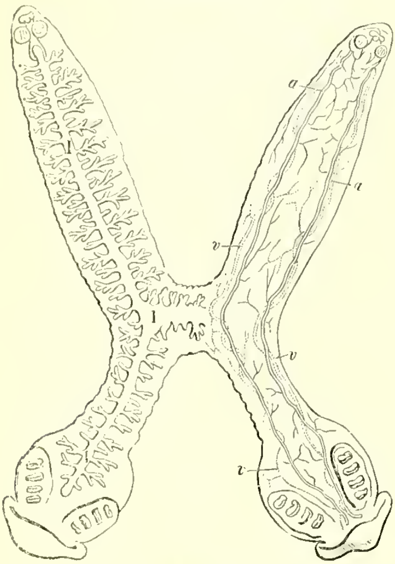
* See the article Arachnida, p. 206.

* Annal. des Sciences Natur. xv. p. 160.

mosing vessels. The larger parts of the longitudinal vessels have been observed to contract and dilate; but neither a regular progressive circulation, nor a connection of the vascular with any distinct respiratory system has as yet been detected.

Entozoa.—In the Entozoa, organs of circulation somewhat similar to those just mentioned in the Planariæ have been found by Bojanus and Mehlis in the Distoma and Tristoma, and by Nordmann* in those remarkable small Entozoa inhabiting the aqueous chamber of the eyes of some quadrupeds, the Diplostomum, and in the Diplozoon. In the first of these animals, the motion of fluid in the vascular system is exceedingly obscure; but in the Diplozoon (*fig.* 328), Nordmann saw, with

Fig. 328.



Diplozoon.

a high magnifying power, currents moving in opposite directions in two sets of vessels (*a*, *v*) placed on each side of both limbs of the animal. These vessels, termed external and internal, are said to terminate posteriorly in a dilated bag, to which Nordmann gives the name of receptacle of the chyle. The organs of circulation of the Diplozoon differ, therefore, in this respect from those of the Planaria, to which otherwise they bear considerable similarity; for, in the latter animal, the vascular system appears to be entirely closed. According to Nordmann and Ehrenberg no contractions or dilatations of the vessels are visible.

Acalephæ.—In some of the Medusa tribe, or Acalephæ, there appears to be no distinct circulatory apparatus; and we observe that in these instances, the alimentary cavity is of great extent and is often much ramified on the surface of the animal.

In others there are distinct vessels with a circulation of fluid within them. The distribution of this very simple kind of vascular system was first discovered by Eschscholtz, who has described its form particularly in the Cestum and Beroe. In the latter animal, it is stated that eight arterial vessels and two veins unite with a large annular vessel which surrounds the mouth, and, according to Eschscholtz's* conjecture, another vascular ring, situated at the posterior extremity of the body, forms the means of communication between the arteries and veins in that region. Branches pass from the external or arterial vessels, and from the internal or venous vessels to the fins, which organs seem to serve at once for respiration and for locomotion. Although the motion of a yellowish fluid containing globules has been seen in these vessels, the complete circulation does not appear to have been made out in a satisfactory manner.

Infusoria.—Some kind of circulation is stated to have been observed by Ehrenberg in some of the Infusoria; but this is an observation which, with every confidence in the accuracy of this celebrated microscopic observer, we feel inclined to consider as liable to fallacy, on account of the prevalence of various kinds of ciliary currents in the interior of many of these animals.

Polypi.—We would extend the same remark to the last kind of circulation to which we shall allude, viz. those singular currents of fluid, which were discovered by Cavolini and recently observed by Mr. Lister in some of the Polypiferous Zoophytes. According to the latter observer, in each of the divisions of the stem of the Tubularia indivisa, a current of fluid carrying globules along with it is seen proceeding up one side and down the other. In various Sertulariæ, the direction of the current becomes reversed from time to time. Similar phenomena are to be observed in Campanulariæ and Plumulariæ. The striking analogy which these currents bear to those occurring in the stems of some plants, as Chara and Caulinia, seem to us to bring them under another class of phenomena than those of the vascular circulation of the higher animals. We do not, however, intend to enter upon the consideration of this subject, as it is already fully treated of under the article Cilia.

In concluding our notice of the simpler forms of the circulatory organs, we would remark that one of the great difficulties which retards the acquisition of an accurate knowledge of the function of circulation in the lowest classes of animals, proceeds from our inability to determine, whether currents moving within enclosed spaces in these animals belong to the circulation of their blood and nutritious fluids, or are connected with respiration, locomotion, and other processes of their economy; and this is an obstacle to the progress of the investigation which from its nature we cannot hope soon to see removed.

* Micographische Beiträge, p. 69. Berlin, 1832.

* System der Acalephen. Berlin, 1829. See the article Acalephæ, p. 43.

In the Planaria, Medusa, some Entozoa, and Polypi, the subdivided or ramified cœca of the alimentary cavity *(fig 328, I)* must obviously contribute to the effect of furnishing a supply of digested matter to the different regions of the body, and of thus rendering a distinct vascular system in them to a certain extent unnecessary. But in these simpler kinds of animals, and even in those of them in which distinct vessels have been discovered, we cannot regard such scattered tubes as the only principal means of distributing the nutritious fluids to the different parts of the body. They may assist in bringing this about; but it is also necessary to suppose the occurrence of an interstitial movement or organic transudation of the fluids, in order to furnish to all the parts the materials for assimilation.

III. Phenomena of the circulation and powers moving the blood.

In proceeding to the third division of our subject, viz. the phenomena of the circulation and the powers by which the blood is moved, we would remark, that, however desirable it might appear in a systematic work of this kind to treat of these two subjects under distinct heads, such a separation would have the effect of detaching inconveniently the facts from the legitimate conclusions which may be drawn from them. We shall first state the phenomena and causes of the motion of the blood which belong strictly to the organs of circulation themselves, and afterwards shall treat of various circumstances connected with the other functions by which the circulation is modified. In this view it is our chief object that the facts adduced should bear upon the explanation of the motion of the blood in the human body, but from the nature of the investigation the facts themselves must be drawn chiefly from experiments made upon the lower animals. Of course those experiments and observations which have been made on Mammiferous animals have most value in relation to such a view of the function as that which it is our intention to give. The order which we shall follow is founded on the course which the blood pursues. We shall treat, 1, of the passage of the blood through the heart; 2, of its flow in the arteries; 3, of its passage from the arteries to the veins through the capillaries; and 4, of its flow in the veins.

1. *Flow of the blood through the heart.*—That the muscular contraction of the heart is, in man and in all animals in which this organ exists, the principal source of the power by which the blood is propelled in its course, seems to be satisfactorily proved by the facts, that whenever the action of the heart ceases or is impeded, the whole circulation ceases, and that, when an obstruction prevents the action of the heart from reaching the blood in any of the bloodvessels, the flow of blood ceases almost instantaneously in all the branches proceeding from the obstructed vessel. The constant and regular persistence of the contractions of this muscular organ from the commencement of life to its termination, the early period at which it begins to act in the fœtus, viz. before any regular circulation of blood takes place, and the existence of a heart or some similar contractile organ in all those animals in which a regular circulation of blood or nutritious fluids occurs, are confirmatory of the view suggested by direct observation and experiment. Under the article Heart will be found a detailed account of the structure and functions of this organ; in this place we shall only state, in as few words as we can, what seems to have been best ascertained regarding its action, in so far as this appears to have a reference to the force of impulsion and direction which it communicates to the blood.

The action of the heart may be observed by opening the chest of a living animal, or for a short time in one immediately after death, or best of all in an animal deprived of sense and motion by poison, and in which artificial respiration is maintained; it has also been seen in children born with ectopia cordis, or in persons in whom from accident a part of the heart has been exposed to view. When observed under one or other of these circumstances, the action or contraction of the whole heart is seen to consist of two motions, viz. 1, the contraction or systole of the auricular part, and 2, that of the ventricular part of the organ. The contraction of the auricle immediately precedes that of the ventricle and seems to be continued into it, and the systole of each cavity is immediately followed by its diastole or relaxation.* After the relaxation of the ventricle, there is a period of repose, or a pause in the action of the heart, during which motion seems to be nearly suspended. At the moment when the systole of the ventricle takes place, the heart appears to be diminished in all its dimensions, and exactly at the same instant of time, the apex is seen to be moved towards the sternum, in whatever position the animal is placed. This tilting forwards of the apex gives the heart a pulsation against the ribs that can be felt externally. This pulsation probably depends on the arrangement of the muscular fibres of the heart, as the raising of the apex occurs when the heart is removed from the body and is empty of blood. At the time of the systole the heart is thicker and more conical in its figure than during the diastole; when held in the hand it feels hard, and the ventricles appear to have propelled the whole of the blood out of their interior, as far as one can judge from the great diminution in their size. In the inferior animals, as Reptiles and Fishes, its colour is lighter from the expulsion of the blood. During the relaxation or diastole, the heart appears to fall away from the

* In some of the lower animals, in the fœtus of the Bird at an early period, and in warm-blooded animals when the action of the heart is weakened, as at the approach of death, the contraction is seen to begin in the venous sinus of the auricle, extend through it to the ventricle, and from one part of the ventricle to another in a gradual manner. In the Batrachia, the contraction begins in the veins, and after passing through the auricle and ventricle, extends into the commencement of the aorta.

chest, its parietes become flaccid, and it assumes a flattened form. The pulse in the arteries, which is in truth nothing more than the communication of the impulse of the heart along the blood in these vessels, corresponds, at least in the larger arteries near the heart, very exactly in time with the ventricular systole and the beat on the walls of the chest. The action of the heart is accompanied by two sounds, that can be heard on applying the ear to the cardiac region. The first of these sounds is synchronous with the systole of the ventricles, the second with their diastole; the second follows the first immediately, and is succeeded by an interval of silence. Of the space of time in which a full action of the heart is completed, the systole of the ventricle occupies nearly a third, the systole of the auricle less than a quarter; the dilatation of the ventricle and repose taken together must be effected in the remainder.

The heart, from its structure and action, may justly be considered as a living or self-moving double forcing-pump, which is continually filled at one part and emptied at another. During one-third of the time of a complete action of the heart, the blood in the arteries is impelled onwards by the direct impulse of the ventricles at their systole. During the other two-thirds of the time, while the ventricle is inactive, the communication between its cavity and the great arteries is stopped by the closure of the semilunar valves, and the blood must, herefore, at this time be propelled by the elastic and other forces of the arteries themselves. But the heart continues to receive blood from the veins during a longer time than it gives out any of that fluid, for the auricles offer a resistance to the entrance of blood during only a space of less than a quarter of the time employed in a complete action of the heart, and the blood is continually impelled into the auricles as well as the ventricles during the whole time that these cavities are not contracted, although more blood enters the auricles immediately after their relaxation, and more is propelled into the ventricles just before their contraction than in the rest of the time.

During the systole of the ventricles, while the stream of blood issues from their cavities into the first adjoining parts of the large arteries, the folds of the semilunar valves are laid close to the inner side of these vessels. As soon as the contractile force of the ventricles ceases, the free edges of the semilunar valves are brought towards the middle of the vessel, and applied firmly against one another so as to close the ventriculo-arterial orifices: this is effected by the pressure of the column of blood acted upon by the elastic coats of the arteries, assisted perhaps by the elasticity of the borders of the valves themselves and by the change of position consequent on dilatation of the ventricles.

During the systole of the ventricles, the auriculo-ventricular or tricuspid and mitral valves are closed, so as to prevent in a great measure regurgitation of the blood from the ventricles into the auricles. When the ventricles are in the relaxed state, the valves are opened by the stream of blood flowing from the auricles. The circumstance that the free margins of the mitral and tricuspid valves are bound down to the inner walls of the ventricles by the tendinous cords attached to the fleshy pillars, and that, by the contraction of these pillars, the free margins of the valves must be pulled further down into the ventricle than in the relaxed state, has occasioned to some a difficulty in understanding their action, and led them to suppose that the columnæ carneæ must necessarily be relaxed at the time of the ventricular systole, and that by contracting while the ventricle is in its diastole, the fleshy pillars contribute to open the valves. The direct observation of the contraction of the columnæ carneæ in the heart of an animal taken from the body, and an attentive observation of the structure of these valves, from which it appears that the tendinous cords passing to opposite flaps of the valves frequently come from the same columnæ carneæ or point of attachment in the ventricular paries, sufficiently prove that these fleshy pillars actually contract at the same moment as the rest of the parietes of the ventricles, and that their contraction, besides drawing the free margins of the valves downwards into the ventricles, must also tend to make them approach one another more nearly; and we are therefore entitled to form the conclusion, that, while the tendons serve to fix the valves, the action of the columnæ carneæ is to draw these down so as to allow the blood to pass behind them, and to press them together and close them in the same manner as the semilunar valves of the aorta and pulmonary artery are shut.

The apparently greater facility of the entrance of blood into the heart at one time than at another, has given rise to the opinion entertained by some physiologists that the dilatation of the heart is, like the contraction, accompanied with the production of a new force, which draws the blood from the veins towards the heart. Some who regard muscular elongation as a source of new power have gone so far as to suppose that this force is even greater than that accompanying contraction, but it is manifest that such a view is opposed by every thing we know of muscular action, which leads to the belief that the shortening of muscular fibre ought alone to be considered as an active, and the subsequent elongation as entirely a passive change. Others suppose the ventricles of the heart to dilate in consequence of elasticity, in the same manner as a bag of caoutchouc does after being compressed with some degree of force. Attempts have even been made to measure the extent of the force produced during the dilatation of the ventricles, by endeavouring to ascertain the weight which is displaced by this motion of the heart. We would not wish to be understood to deny the possibility of the heart's exerting some slight force in this way during its dilatation, but it appears very clear that a measurement of the kind referred to must be so difficult as to be almost useless; indeed, it is very probable that some have mistaken the contraction for the dilatation, and we shall afterwards find that the power of suction, exerted by the heart on the blood, as measured by the force with which the veins are emptied, is very small indeed. It is clear that the blood driven on from behind by a propelling power, or flowing through parts which are pressed upon by neighbouring organs, must enter the heart more easily during the relaxation of the parietes of the ventricle than at any other period during the heart's action, so as to give rise to an appearance of suction, but direct experiments make it sufficiently obvious that the force of impulsion from behind is *almost* the sole cause of the entrance of the blood from the trunks of the great veins into the cavities of the heart.

In order to form an estimate of the time in which a given quantity of blood may pass through the heart, or of the time in which the whole quantity of blood contained in the body would take to pass through the heart, several data are required which are not yet furnished by accurate experiments. In the first place, we must know the average quantity of blood contained in the body, and, in the next place, the quantity which is evacuated from the heart at each stroke or systole of the ventricles.

With regard to the first of these points, a number of calculations have been made which vary greatly in their results. Animals have been bled to death by the section of the larger bloodvessels, and the quantity of blood lost has been measured. The quantity of blood lost in this way seems to have varied from 1-10th to 1-30th of the weight of the whole body, and Dr. Moulins, who formed his estimates from experiments of this kind, rated the quantity of blood in the human body at eight or nine lbs. only, or 1-20th of the weight of an average sized man, taken at 150 or 160 lbs. But it is obvious that when one of the larger bloodvessels is opened, from the suddenness of the flow, the animal faints or dies before the whole or even a considerable proportion of the blood has been lost; and it has been ascertained from numerous observations, that when the blood flows more gradually and from small vessels, as occurs in hemorrhages from the nose, stomach, rectum, or uterus, a proportionally much greater quantity of blood may be lost than occasions death in animals experimented upon by the section of the larger arteries or veins. Instances are on record in which from ten to twenty lbs. and even greater quantities of blood have flowed from the human body within twenty-four hours.* We feel inclined on these grounds to coincide with the estimate formed by Haller, that the blood forms about a fifth of the weight of the body, or equals from twenty-five to thirty lbs. in a man of the average weight of 150 lbs. It is obvious that this must vary in different individuals from other circumstances besides a difference of stature. In the young, the quantity of blood is considered to be greatest. Of the whole of the blood contained in the body, it is estimated by Haller, and probably with accuracy, that four parts are contained in the arterial and nine in the venous system.

In endeavouring to estimate the quantity of blood which passes through the heart in a given time, we must find the capacity of the cavities of the heart, we must ascertain whether the cavities on the two sides are of the same size, and, as it is almost impossible to measure the quantity of blood evacuated from the heart at each stroke, we must find to what extent the ventricles empty themselves during their systole. It is obvious that, so long as the circulation is uniform and no local accumulation of blood takes place, the same quantity of blood must pass out of the ventricles into the larger arteries which enters by the veins, and for the same reasons, that the quantity of blood passing through the right and left cavities of the heart must be exactly equal. The circumstance that an equal quantity of blood passes out of the right and left cavities of the heart during their systole does not entitle us to conclude that the capacity of the different auricles and ventricles is the same, because any one of them during its systole may be more or less completely emptied than the rest, and a regurgitation obviously takes place from some of them, so that the whole blood which they contain is not propelled in its onward course. According to some anatomists the auricles are larger in capacity than the ventricles, probably in the proportion of three or two and a half to two, and the auricles are by no means completely emptied during their systole. An opinion has very generally prevailed that the cavities on the right side of the heart are somewhat larger than those on the left. There is no doubt that in making measurements of the relative capacity of the two sides after death, it is most frequently found so; but it is obvious that some have very much overrated the difference, and there is much reason to believe that the greater capacity of the right auricle and ventricle depends in part on the accumulation of blood which generally takes place in most kinds of slow death in the pulmonary arteries, and in part also upon the greater thinness and consequent distensibility of the right ventricle. In men dying suddenly, and in animals killed purposely, in which the pulmonary artery is opened so as to allow of the free egress of the blood from the right side of the heart, the capacity of this ventricle is not greater than that of the left, and the proportions of the capacity of the two sides of the heart usually found after slow death are sometimes reversed when a ligature is placed on the aorta and the pulmonary artery is opened.* Most authors seem to have agreed to follow the estimate of the capacity of the ventricles given by Hales in his Medical Statics. This author esti-

* See Haller's Elementa, and Keill on the An. Econ.

* Sabatier.

mates the capacity of the left ventricle at 1½ oz. fluid measure, and that of the right at 2 oz. The contemplation of the muscular structure of the left ventricle, and the great diminution in size it undergoes during its systole, would induce us to conclude that it must be completely emptied during the contraction, and that there cannot remain any blood even among the columnæ carneæ. The right ventricle does not appear from the quantity of its muscular substance to be so well suited to be emptied, but its position round the left must assist considerably in the diminution of its size during its systole. In some cases of sudden death in healthy persons, both ventricles have been found completely empty.

The whole of the blood issuing from the ventricles into the first parts of the great arteries is retained within these arteries by the action of the semilunar valves, and it would appear that in the healthy condition the adaptation of these valves is such that very little if any blood regurgitates or flows backwards into the ventricles. At the time that the auricles contract, a very different phenomenon presents itself, for while a certain quantity of the blood from the auricles passes onwards into the ventricles, some is driven back into the orifices of the great veins. This venous regurgitation is particularly evident in the veins connected with the right side of the heart, the orifices of which have no valves or very imperfect ones; and it gives rise to a pulsation in their larger branches, synchronous with the systole of the auricle, as may be seen in most thin persons in the jugular vein at the lower part of the neck. It would appear that upon some occasions, even in the state of health, a certain back stroke from the ventricles also is perceptible in the veins, and Hales was of opinion that some of the blood (half an ounce) from the right ventricle flowed back into the auricle during each systole of the ventricle. It must be apparent that immediately after the auricle has ceased to propel its contents into the ventricle, and just when the systole of the ventricle begins, the column of blood extending from the ventricle into the auricle through the auriculo-ventricular orifice must be continuous, and the pressure of the ventricular systole must thus be transmitted upwards until the valves flap together and close that opening. Accordingly, in some persons in health, a venous pulse, synchronous with the ventricular systole, is occasionally seen or felt in the jugular veins, but this appearance is much more commonly a sign of disease; for the venous pulse which is synchronous with the ventricular systole is much increased when an obstacle presents itself to the free flow of blood through the pulmonary artery, or when from ossification or other morbid alteration, the auriculo-ventricular valves do not close accurately the passage in which they are placed.

We may conclude, from the observations above alluded to, that on an average each of the ventricles of the heart gives out nearly one ounce and a half at each stroke; and we may now state the general calculation of the time that the blood takes to move through the heart, which is generally founded upon the above data. Let us suppose the heart to beat seventy-five times in a minute, which is nearly the average number of pulsations in a healthy man in the prime of life, and assume the quantity of blood in the body at 28 lbs.; and let us suppose that 1½ oz. of blood is expelled from each ventricle into the great arteries connected with them, then 112 oz. or 7 lbs. of blood would pass through each ventricle in a minute, and 28 lbs. in four minutes; or in three minutes, if the quantity of blood passing through the ventricles at each systole be estimated at two ounces, i. e. a quantity of blood equal to that which we conceive to be contained in the whole body, would flow through the heart in the short space of four minutes, and this quantity would run the same course fifteen times in an hour. We must guard against conceiving, on the one hand, that this calculation affords any accurate measure of the quantity of blood which actually passes through the ventricles in a given time, for there are innumerable circumstances which tend to cause this quantity to vary to a considerable extent; and on the other hand, it must at all times be borne in mind that we can, from such calculations, estimate only the velocity of the blood in the heart itself, or the time which a certain quantity of blood takes to pass through its cavities, but that we are not furnished with any measure of the time that the whole of the circulating quantity of blood actually takes to pass through its course, for the length of the courses through which the blood has to pass in different parts of the vascular system varies to such a degree, that in some places, as for example in the bloodvessels of the heart itself, the return to the heart must be effected in less than half the time employed by that which is transmitted to the extremities. On comparing the longest or shortest calculations of this kind made by different authors, we shall find that the time of a circulation is made to vary from six minutes and a half to one minute.

We shall not at present enter upon the consideration of the force with which the blood issues from the left ventricle of the heart, as the experiments by which this force is determined being made upon the arteries, come more suitably to be treated of under the arterial circulation.

2. *Phenomena of the arterial circulation.*—In proceeding to consider the phenomena and causes of the flow of blood through the arterial system, we purpose to treat of, 1st, the velocity; 2d, the force of the blood in the arteries; 3d, the nature of the arterial pulse; 4th, the vital properties of the arteries; and 5th, the influence exerted by this class of bloodvessels on the circulation. We shall find that, in this part of our subject, the difficulty of becoming acquainted with the immense variety of circumstances capable of modifying the flow of the blood, has prevented the explanation of phenomena which are in themselves sufficiently simple and apparent. In our remarks upon the above-mentioned topics, we shall endeavour to

refer the phenomena of the circulation, as far as we can, to hydraulic principles, which, when correctly applied, must form the only sure guide in conducting a physiological inquiry of this nature.

The flow of the blood, as it is expelled from the left ventricle, may be said to be intermittent, for it moves only at the time of the ventricular systole. Farther on in its course, in the larger as well as the middle sized arteries, the flow of blood is remittent, or is more rapid after each beat of the heart, and by the time it arrives at the capillary vessels and commencement of the veins, the velocity is rendered perfectly uniform. The effect, therefore, produced by the arterial tubes is to convert an intermittent, first into a remittent, and afterwards into a uniform force. When an opening is made into one of the larger arteries, the jet of blood which issues is regularly increased in velocity at every systole of the ventricle. In the very small arteries, this acceleration of the stream becomes less perceptible. We know that it has altogether disappeared in the smallest vessels or capillaries, from microscopic observation of the flow of the blood in them, and the uniformity of the velocity of the stream in the veins is clearly shewn in all instances in which a vein is opened, as in the common operation of bleeding from the arm.

Various circumstances shew that in the living body the blood forms an uninterrupted column of fluid in the bloodvessels, and that the whole vascular system is kept in a state of forced distension by the reiterated impulses communicated to the blood by the ventricular contractions. Besides the general fulness of the bloodvessels and their connection with the heart, we may mention as proofs of the distended state of the vascular system, the facts, 1st, that, on opening any of the bloodvessels, the blood issues with greater force at the first moment than afterwards; and 2d, that when we imitate the propulsion of the blood through the arteries and veins by artificial injection of fluids in a dead animal, we observe that the jet from an opened vessel continues to flow for some time after we have ceased to drive the piston of the syringe. The arteries being much stronger than the veins, re-act with greater power than they do against the distending force of the heart. Were the arteries rigid tubes, it is manifest that in a given time just as much blood would pass from their remote extremities into the commencement of the veins, as enters them by the mouth of the aorta; but the arteries must be fuller at one time than another, for the quantity of blood expelled from the ventricle at each systole, must pass suddenly into the first part of the aorta, while an equal quantity of blood, which must necessarily pass from the remote arteries into veins, as it moves uniformly, must employ the whole period of time occupied by a complete action of the heart in its passage; and consequently it is manifest, that the arterial system must be fuller just after than immediately before the contraction of the ventricle. The arteries are distensible and elastic, they yield a little to every successive stroke of the ventricle, and during the diastole they re-act by their elasticity, so as to keep up the flow of blood. We have already said, in speaking of the heart, that the muscular contraction of that organ is the chief, if not the only source of the power propelling the blood. It is only in those arteries which are nearest to the heart, however, that the blood can be said to be propelled by the direct impulse of the ventricle, for in the rest of the arterial system, the progression of the blood is immediately effected by the elastic power of the arteries, called into operation in consequence of their distension by the action of the heart. In the experiments of artificial injection of the bloodvessels in dead animals already mentioned, as long as we continue to drive the piston of the syringe, and to propel fluids through the arteries into the veins, the arteries are kept in a state of forced distension; in consequence of this, the fluid issues from an opened artery with a jet accelerated after each successive stroke of the piston, and continues to flow for some time after the propelling power has ceased to act. The uniformity of the stream of fluid from the veins, which occurs in the same experiment, is a proof that the continued flow of blood in these tubes may, in the living body, be owing to an impulsion from the heart, transmitted by the arteries, and that it is caused by the elasticity of the coats of the vessels themselves.

a. Velocity of the blood in different arteries. The space of the aorta filled up by the blood propelled from the ventricle at each systole, divided by the time occupied in its propulsion, constitutes the velocity of the blood in the first part of the aorta. The diameter of the aperture of the aorta at the ventricle being taken as on an average 1·12 of an inch,* its area would be one square inch, and consequently $1\frac{1}{2}$ oz. which equal 2·45 cubic inches of blood, would occupy a little more than 2·5 inches of the aorta, supposing its size to be for such an extent of a uniform diameter. As it is satisfactorily ascertained by actual measurement, that the blood contained in the smaller vessels is in much greater quantity than that in the larger trunks; or, in other words, as the capacity of the smaller vessels taken together is greater than that of the larger, it will at once be apparent, that the velocity of the blood must diminish in passing from the larger to the smaller vessels. The arterial and venous vessels may in fact be regarded as two hollow cones, curved so as to be joined at their apices to the heart, and at their bases to one another. The veins, being more numerous and wider than the arteries, must be represented by a wider cone. The section of these cones at any place is supposed to give the combined area of the section of the vessels at a corresponding distance from the heart.

The estimates made by different authors of the relative velocity of the blood in the larger and smaller vessels, differ in a great degree,

* The aperture of the aorta is somewhat less than one inch in diameter in most persons; we may, however, adopt the above estimate of its size, as the sinus of the aorta is much wider than its aperture.

and are exceedingly unsatisfactory. Haller, who fully admitted the greater capacity of the smaller arteries, and allowed that the flow of the blood must therefore, from hydraulic principles, become less rapid in passing from the trunks to their branches,—a proposition which he illustrates by comparing the stream of blood in its passage to a river which enters a lake,—was yet inclined, from the result of his actual observations, to deny that the velocity is much less in the smaller than in the larger arteries. Spallanzani, although admitting more explicitly still than Haller the necessity of such a retardation, seems to have met with the same difficulty in reconciling theory with his attempts to measure the velocity of the blood in the small vessels: and both these authors state, that although the circulation was in general comparatively slow in the web of the frog's foot, still in many instances in this situation, and more frequently in the mesentery, they were unable to detect any difference in the rapidity of the flow of the blood in the larger and smaller arteries.*

Hales, again, states as the result of his observations and measurements, that the velocity of the blood in the smallest capillaries of the abdominal muscles of the frog, is so small as one or one and a half inch in a minute; and, from the attempts which we ourselves have made at these measurements, we feel inclined to agree with the statement of this able experimenter, having, upon several occasions, ascertained that in those capillaries which admit only two globules of blood, the velocity is not greater than the hundredth part of an inch in a second; but it seems doubtful whether in all the capillaries the velocity is so small as in those just alluded to, and in the larger capillary vessels of the diameter of six globules, when no unnatural obstruction to the circulation in the limb occurred, independently of the difficulty of fixing the eye upon any globule in such a way as to trace its progress along the vessel, the velocity has always appeared so great as to prevent the possibility of measuring it; and we are at a loss to conceive in what manner Haller made the comparison he speaks of between the velocity in the larger and smaller arteries. By means of the microscope, it is easy to see that the velocity is greater in the small arteries than in the corresponding veins, which are both more numerous and considerably larger than the arteries.

The results of actual observation of the flow of the blood and of the measurement of the relative capacities of different arteries, afford as yet very unsatisfactory data upon which to found an estimate of the relative velocity of the blood in the trunks and branches of the arteries. In the absence of more direct means of calculation, an approximative estimate may be made in another way, viz. by comparing the quantity of blood which occupies a known space of the larger vessels with the whole quantity of blood contained in the body.

We have already seen that the whole blood in the body may be estimated at nearly thirty pounds: now, let us suppose the aorta and pulmonary arteries, together with their returning veins, to form a continuous tube of the length of the two courses of the blood, in the systemic and pulmonic circulations, and of the same diameter as these vessels at their point of junction with the heart; a very simple calculation shews us that such a tube is capable of holding only about six pounds and a quarter, or less than a fourth part of the whole blood of the body; or in other words, were the aggregate capacities of the small vessels no more than equal to that of the larger, they would be capable of holding only a fifth of the blood contained in the body.

The velocity of the blood in the commencement of the aorta may be considered as two and a half inches in a second, for this is the space occupied by all the blood which is propelled into the aorta from the left ventricle in that time, and according to the arbitrary modes of estimating the relative capacity of the aorta and its branches here employed, the velocity of the blood in the aortic capillaries generally, might be considered as one-fourth of that in the commencement of the aorta, or nearly half an inch in a second, a result widely different from that obtained by Hales.

Attempts have also been made to estimate the velocity of the flow of blood, by observing the time which certain substances, when introduced into one part of the vascular system, take to pass to another. The most remarkable series of experiments of this nature with which we are acquainted were performed by Hering.* This author states that he has been able to detect prussiate of potassa, which he had introduced into one of the jugular veins of a horse, in the blood drawn from the opposite jugular vein in the space of from twenty to thirty seconds; and he has formed the conclusion from this experiment that the prussiate of potass, in order to gain the jugular vein on the opposite side of the body, had passed in this remarkably short space of time through the whole course of the double circulation: that it was first carried to the heart, then passed through the pulmonary arteries and veins, and returned to the heart, from which it must have been transmitted through the ultimate ramifications of the systemic arteries before being brought back by the veins, in which it was found on the opposite side of the body. Hering states, as the result of other experiments of a similar nature made upon different bloodvessels, that the prussiate of potassa passed from the jugular vein to the saphena vein in twenty seconds; to the masseteric artery, in fifteen to twenty seconds; to the external maxillary artery, in ten to twenty-five seconds; to the metatarsal artery, in twenty to forty seconds.

We consider these curious experiments as important in many points of view, but do not feel inclined to concur in the conclusion deduced from them by their author, that the

* Haller appears to mean here arteries of considerable size.

* Tiedemann's Zeitschrift, vol. iii. p. 85.

circulation of the blood, rapid as it may be, takes place in this remarkably short space of time, and we are disposed to suspect that the experiments themselves are liable to several sources of fallacy. The tendency of the prussiate of potass to permeate the textures of the body, more freely than any other substance known, has been proved by many experiments, and it is therefore necessary that Hering's experiments should be performed with some other substances, before they can be regarded as a correct means of estimating the rapidity of the circulation.

The velocity of the blood is generally believed to be greater in the pulmonic than in the systemic circulation,—an opinion founded chiefly on the supposed less capacity of the vessels belonging to the pulmonary trunks. Actual measurements of the velocity of the blood in the capillaries of the lungs of cold-blooded animals by Hales, Spallanzani, and others, would seem to give support to this view, but it must at the same time be recollected that the course through which the blood passes in the pulmonary or lesser circulation, is considerably shorter upon the whole than that of the systemic or greater,—a circumstance which must diminish to a certain extent the disproportion in the velocity.*

b. Force of the blood in the arteries and force of the heart.—Another interesting inquiry connected with this subject relates to the force with which the blood is impelled in the arteries, and the calculations that have been made of the power of the heart itself, from the observation of the force of the blood in the arteries. The experiments made with a view to discover these forces appear sufficiently simple in their nature; but the calculations founded upon the experiments have differed so widely, as to have furnished a plausible pretext for throwing ridicule on the application of physical laws to the living animal functions.

As the arteries and other vessels are kept distended with blood by the action of the heart, it follows that were they rigid tubes, the force of the heart would, in accordance with the laws of propagation of pressure through fluids, be transmitted without loss through the whole column of blood in the arteries at one and the same moment: but in consequence of their yielding to distension, the force of the heart operates upon the blood only through the elastic reaction of the coats of the arteries.

When an opening is made into one of the larger arteries, the blood issues with force, and spouts to some distance, but the height to which the blood rises when allowed to escape from a simple aperture in an artery varies from many accidental circumstances, and cannot therefore be taken as affording an accurate measure of the force with which the blood moves within the vessels.

Hales seems first to have investigated this force in a more accurate and experimental manner, by observing the weight which the blood in one of the arteries of a living animal is capable of sustaining within a tube adapted to it. He remarked that the blood issuing from a simple aperture in the carotid artery of a horse and directed upwards did not rise above three feet,* but that when the blood was allowed to pass into a long glass tube adapted to the same artery it rose very quickly to a much greater height, as to nearly ten feet in some of the experiments. Hales performed similar experiments on the arterial flow in sheep, oxen, dogs, and other animals, and after observing for each the pressure which the blood in the arteries is usually capable of exerting, he endeavoured to compute the pressure of the blood in the arteries of man, by a comparison of the size of his whole body or heart and bloodvessels with those of the other animals. The pressure of the blood in the aorta of the horse being considered as eleven pounds, Hales estimates in the way above-mentioned the force of the blood in the human aorta at 4 lbs. 6 oz.; seven and a half feet being the height to which he supposed that the blood would rise in a tube connected with the larger arteries of a man.

These experiments of Hales shewed in a very clear manner, that the height to which the blood rises in one of the larger arteries affords us the means of ascertaining directly the amount of pressure which the stream of blood impelled by the heart through the arteries is capable of exerting at any part of the arterial system, or in other words it gives us a measure of the statical force of the heart as it operates through the arterial tubes.†

According to a well-known law of physics, the heart must be pressed upon in every part of its internal surface by the column of blood which it has raised; so that by multiplying the area of the internal surface of the ventricle into the height of the column of blood supported in the tube connected with an artery, we shall ascertain the pressure which acts backwards on the inner surface of the heart. Hales estimates the inner surface of the ventricle of the human heart at fifteen square inches, and multiplying the pressure of a co-

* In reference to the above calculations, it must also be kept in mind, in the first place, that the estimate of the velocity of the blood in the pulmonic circulation in the frog can scarcely with propriety be applied to man, seeing that in the frog the pulmonary artery is only a branch of the aorta; and, in the second place, that in animals with a double circulation, although the quantity of blood which leaves both sides of the heart at each systole be equal, it does not necessarily follow that the whole blood which circulates through the system should in the same time pass through the lungs.

* This experiment we have repeated with Mr. Dick's assistance.

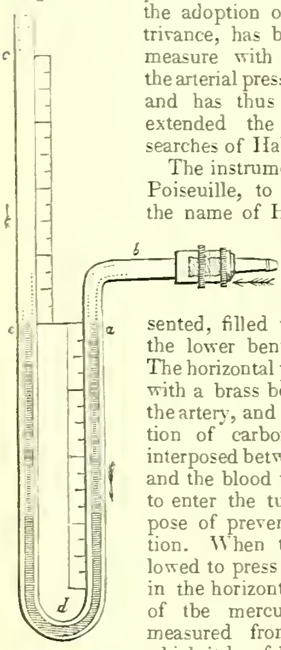
† These experiments, as well as others subsequently performed, demonstrate the importance of confining our researches in an inquiry of this nature to the estimation of the statical force operating in the organs of circulation, as the only useful object of such calculations,—the propriety of which is also sufficiently apparent from the extraordinary results of the attempts to estimate the dynamical power of the heart or the whole force generated in that organ by muscular contraction, by Borelli and Bernouilli, the first of whom calculated this force to equal 180,000, the second 3,000 lbs.

lumn of blood of seven feet and a half high into the area of the inner surface of the heart: he hence calculates the pressure on the inner surface of the human heart to be nearly $51\frac{1}{2}$ lbs. The pressure on the interior of the horse's heart he estimates at 113 lbs. upon similar principles.

As pressure applied in any direction to a fluid column is equally transmitted through all its parts, and as the blood in the arteries forms continuous columns which all branch off from the aorta, it might *a priori* have been concluded that the force of the blood must be the same in all the arteries of any considerable size. Hales, though he does not state this proposition very explicitly, seems yet to have taken it for granted; for, in estimating the pressure of the heart, he takes into account merely the height of the column without reference to the size of the artery. We shall find this proposition to be satisfactorily proved to be correct by direct experiments subsequently performed.

The experiments of Hales were liable to two principal objections: 1st, that the coagulation of the blood in the long glass tube adapted to the artery must have prevented its free motion; and, 2nd, that the length of the tube, besides giving rise to the necessity of frequently removing it and various other inconveniences, must have occasioned a considerable loss of blood in filling from the arteries of small animals. Both these sources of fallacy have been provided against most successfully by M. Poiseuille,* an ingenious experimenter of Paris, who, by the adoption of a simple contrivance, has been enabled to measure with great accuracy the arterial pressure of the blood, and has thus confirmed and extended the interesting researches of Hales.

Fig. 329.



Poiseuille's Hemadynamometer.

The instrument employed by Poiseuille, to which he gives the name of Hemadynamometer, (*fig.* 329,) consists of a bent glass tube of the form here represented, filled with mercury in the lower bent part (a, d, e). The horizontal part (b), provided with a brass bead, is fitted into the artery, and a little of a solution of carbonate of soda is interposed between the mercury and the blood which is allowed to enter the tube for the purpose of preventing its coagulation. When the blood is allowed to press upon the fluid in the horizontal limb, the rise of the mercury towards (c) measured from the level to which it has fallen towards (d) gives the pressure under which the blood moves.

* Magendie's Journal, vols. viii. & ix. Breschet's Repert. d'Anat. et de Physiol. 1826.

One of the most important facts established by Poiseuille's experiments is, that the pressure of the blood is within certain limits nearly the same in arteries of very different calibre and at different distances from the heart; as proved by the rise of the mercury of the hemadynamometer to nearly an equal height when this instrument was connected with the iliac, carotid, radial, facial, and other arteries in some of the lower animals. It is hence apparent, that, in order to ascertain the whole amount of force with which the blood is propelled in the aorta, or the statical force of the heart itself, it is sufficient to measure by means of the tube the momentum of the blood in any one of the arteries. Poiseuille estimates the force with which the blood is propelled in the commencement of the aorta in man at 4 lbs. 3 oz.,—a result which agrees remarkably with that obtained by Hales.*

Poiseuille, however, considers the pressure backwards within the heart to amount to 13 lbs. only, as he calculates this in a different way from that followed by Hales, viz. by multiplying the pressure of the blood in the aorta into the surface of a plane passed through the base and apex of the left ventricle,—a mode of calculation which it appears that Dr. Hales had not lost sight of; for, at page 21 of the work on Hemastatics, he proposes it as the "means of estimating the force of the blood which the muscular fibres of the ventricle must resist."

Poiseuille estimates the force with which the blood moves in the radial artery of man at four drachms.

Hales had remarked that the blood in the tube connected with an artery rose regularly a little way at each systole of the ventricle, and remained always somewhat higher during the straining of the animal, that is, while the muscles of expiration were in action. These phenomena, known to Haller, were demonstrated experimentally by Magendie, and receive a still more decided confirmation from the experiments of Poiseuille made with the hemadynamometer.†

We would here remark that, it having been shewn by the above-mentioned experiments that the force of the heart is sensibly the same in the trunks and larger branches of the arteries, it is manifest that the angles of ramification and the friction of the blood against the sides of the vessels can give rise to very little if any diminution in the force of the heart transmitted by the elasticity of the arterial parietes. We shall afterwards see that the case is very different in the smaller vessels.

We would also call the attention of the reader to an interesting application of the fact of the complete transmission of pressure through the fluid contained within the bloodvessels in all directions, in the immense force which the

* The power of the heart has also been calculated from the force supposed necessary to raise the foot of one of the legs thrown across the other in the pulsatory movement which is then seen to occur,—one of the most inaccurate methods that could be adopted.

† See Part IV. of this article.

blood occasionally appears to exert within an aneurismal tumour; giving rise to its peculiarly hard pulsation on every side, and assisting the ravages by absorption which are frequently the consequence of the larger internal aneurisms. The pressure in an aneurism is obviously to be measured by the extent of its internal surface multiplied into the force with which the blood moves in the part of the artery where it opens into the aneurismal sac.

c. *Arterial pulse.*—The arterial pulse, or succession of beats felt by the finger placed over an artery, depends upon the impulse of the left ventricle being communicated along the arterial tube and the column of blood which it contains.

When a ligature is put upon an artery, no pulse is felt beyond the place where the artery is obstructed, but it is distinct up to that place. This experiment at once shews the dependence of the pulse on the systole of the ventricle, and establishes that this phenomenon is not dependent on the progressive motion of the blood, since, in that part of the artery placed on the side of the ligature next to the heart in which the pulse is distinct, the blood is at rest. Nor does the pulse appear in ordinary circumstances to depend upon lateral distension of the arteries, for such distension occurs to so small a degree as is quite insufficient to account for the production of the pulse. Arthaud,* a French surgeon, was the first who sustained, in opposition to the opinion prevalent at the time he wrote, the view that the arteries are not laterally dilated at each systole of the heart, and that the pulse is not to be explained by such dilatation. Arthaud shewed that when an artery is laid bare, no perceptible enlargement of its calibre takes place at the time when the heart contracts and the pulse is felt. We have already stated that the arterial system being fuller of blood at one time than another must be dilated to admit the blood propelled into the aorta from the ventricle; and it seems to follow from the observations of Arthaud, which have been ably confirmed by the interesting experiments of the late Dr. Parry,† that the enlargement of the capacity of the arteries is effected principally by their elongation. According to these experimenters, when one of the larger arteries is laid bare, the eye does not distinguish any lateral enlargement corresponding to the systole of the ventricle, and Parry measured with great care the artery at the time of each pulse and between the beats without being able to detect the slightest differences in its size; but though not perceptibly distended laterally, the artery undergoes a certain change of place, for at each systole of the ventricle it is propelled in a direction outwards from the heart, and during the diastole it returns to its former situation. This locomotion of the artery, as it is called, is obviously produced by the distension and elongation of the larger arteries near the heart. A considerable elongation of the arteries may also easily be seen at all sudden incurvations of these vessels. The bend of the curved part is generally increased and projected further outwards during the systole; and we observe that a straight part of an artery, if fixed at its opposite ends, is bent at the time of the pulse in consequence of its elongation. In many persons in a state of health the arteries may be seen to move under the skin, although not exposed. This motion is generally perceived at places where there is a sudden bend of an artery, or where the artery lies upon an unyielding part, as bone, &c., and in some individuals an appearance of dilatation or lateral enlargement even may be perceived in some of the larger arteries. Although these circumstances shew that the pulse is not attributable to a lateral dilatation of arteries, yet it would appear that such an enlargement does occur in a small degree, for it is occasionally perceptible to the eye in the arteries when laid bare; and M. Poiseuille,* by means of a small apparatus, capable of being applied round a part of an artery, has proved distinctly the occurrence of lateral enlargement, and estimated its extent in the larger arteries at 1-11th of their diameter.

The finger laid upon an exposed artery does not feel any pulse, unless the artery be compressed, and when the arteries are in their natural situation covered by the integuments, it is only when they lie upon a hard part, as a bone, and when the sides of the artery are brought nearer to one another by pressure, that the pulse is perceptible. Those instances in which this does not appear to be the case, as well as those in which the dilatation occasionally seems to occur below the integuments, may in like manner depend upon the artery being subjected to pressure of superjacent parts at the place observed. It is also sufficiently obvious that the pulse does not depend upon any active change of the artery itself, or upon any vital contraction and dilatation of the vessels, for the exact appearance of the living pulse may be produced in the arteries of a dead animal by injecting water into the arteries with a syringe, if care be taken to imitate with the strokes of the piston the beats of the left ventricle of the heart. A further proof of this, and an excellent illustration of the nature of the pulse, is obtained from the curious experiment performed by Bichat of connecting the bloodvessels of a living animal with those of a dead one, the result of which is the production of a pulse in the vessels of the dead animal connected with the arteries of the living one. In those instances in which a communication has been established between an artery and a contiguous vein in consequence of a wound, or in what is called Aneurismal Varix, the vein pulsates exactly like an artery.

Many have remarked that the pulse in the

* Dissert. sur la Dilatation des Artères. Paris, 1770.

† Dr. C. H. Parry's Inquiry into the Nature of the Arterial Pulse. Bath and Lond. 1816. Dr. Chas. Henry Parry's Additional Experiments. Lond. 1819.

* Sur la dilatation des Artères; Magendie's Journ. vol. ix. p. 44; and Breschet's Repert. 1828.

arteries of the extremities is a little later than the beat of the heart on the ribs and the pulse in the arteries in the immediate neighbourhood of the heart. This retardation has of late been more distinctly pointed out by Dr. M'Donnell of Belfast,* and by Weber of Leipsig.† It is much more marked in some persons than in others, and is always most perceptible when the circulation is slowest. With a little attention we can thus observe a distinct succession in the occurrence of the beat of the apex of the heart at the ribs, the pulse in the carotid, facial, radial, and posterior tibial arteries, the interval between each of which, though very small, being yet appreciable by the finger. Weber states that the retardation of the pulse in the foot after that of the beat of the heart amounts to not more than one-seventh part of a second. We have ourselves confirmed by experiments on several individuals the most of these facts relating to the later pulse in the more remote arteries. The cause of the retardation is obviously the elasticity and yielding of the arterial parietes; for were the arteries rigid tubes, it is manifest that the impulse of the heart would be felt at one and the same instant of time throughout the whole of the branches; but as these vessels yield to distension, that part of them to which the distending force is immediately applied is first dilated, and this dilatation does not reach immediately the remote parts.

The pulse has been correctly compared to the propagation of an undulation or wave on the surface of water; for the successive impulses of the heart are first given to the column of blood in the commencement of the aorta; this column communicates these impulses to the arterial parietes and tends to distend them. The parietes re-act against this distending force and compress the adjoining part of the column of blood, from which the impulse passes to the next part of the aorta; and so the pulse, gradually passing on from the trunks to the smaller branches, becomes less and less perceptible as the force of the heart is equalized by the elastic resistance of the coats of these vessels.‡

The pulse is still perceptible in very small arteries: Haller§ states that he was unable to perceive any in small arteries of one-sixth of a line in diameter,—an observation which does not, however, prove the flow of the blood to be uniform or without jerks even in vessels of this size, for Spallanzani‖ observed pulsations in arteries of this small size; and the microscopic observation of the circulation in transparent parts by Haller himself, Spallanzani, and others, shews that the visible impulse of the heart is communicated to the blood in the smallest of those vessels, which have distinctly the characters of arteries.

The pulse being nothing else than the beats of the heart transmitted through the arteries, the consideration of the variations in force or frequency to which it is subject belongs more properly to the subject of the functions of the heart. In this place we shall only mention the mean of the usual number of pulsations of the arteries in the space of a minute as they occur at different periods of life.

Child before birth	140—150
Newly-born infant	130—140
Child one year old	120
Two years	108
Three years	95
Seven years	85
Age of puberty	80
Manhood	75
Old age	60—50

d. Vital properties of the arteries.—In the view we have hitherto taken of the arterial circulation we have considered the coats of the arteries as endowed with physical powers only, and we have alluded to no other phenomena of the motion of the blood than those which appear to be connected with their elasticity. We have now to direct our attention to the more strictly vital and contractile powers of the arteries, which constitute them an independent source of force, and to examine how far the operation of such powers may modify the flow of the blood. We shall here discuss more in detail the questions whether the heart is to be regarded as the only source of the power by which the blood is impelled, and the bloodvessels merely as the modifiers or regulators of the force generated by the heart's contraction—or whether the arteries do not, by their own independent power, contribute to the propulsion of the blood.

Physiologists are very much divided in their opinions upon these questions, some regarding the heart as the sole moving power, some supposing the bloodvessels to be the principal, the heart a subordinate cause of motion; and others adopting various modifications of these opposite views. Many who agree in considering the heart's action as insufficient to propel the blood through the smaller bloodvessels into the veins, differ as to the cause of the additional power supposed necessary for the maintenance of the circulation; the larger and middle sized arteries being looked upon by some as highly contractile, and in consequence of this, the agents of propulsion; the capillaries being regarded by others as the most efficient promoters of the flow of the blood within the bloodvessels. We must, for the present, confine our remarks to the first of these, or the opinion that the larger arteries are mainly or in part the agents of the propulsion of the blood.

That the arteries have the power of changing, to a certain extent, the quantity of blood which passes through them, and of thus modifying the circulation by their own independent powers, there can be no doubt, from the occurrence of unequal distributions of blood, or of local de-

* At the Meeting of the British Scient. Associat. in Dublin.

† De pulsu in omnib. arter. plane non synchronico. Annot. Academ. Leipzig, 1834.

‡ Young's Croonian Lecture on the Functions of the Heart and Arteries, in his Introduction to Medical Literature.

§ Mém. sur le Mouvement du Sang. Laus. 1756. Translated.

‖ Expér. sur la Circulation, in French, by Tourdes. Paris, An 8. In English, by Hall. Lond. 1801.

terminations of that fluid which take place in blushing, inflammation, and other states of the economy in which particular parts of the vascular system become more or less filled with blood than usual; for such variations in the distribution of the blood would be impossible, were an alteration in the powers of the heart alone the only means of modifying the circulation. The questions, however, whether such powers as are possessed by the arteries contribute upon the whole to the progressive motion of the blood or modify only its distribution, are quite distinct from one another.

In its anatomical structure the fibrous coat of the arteries differs considerably from muscular substance, and appears to resemble more nearly the yellow elastic ligamentous tissue. Its fibres are less mixed with cellular substance than those of muscles; they are also more dry, hard, and friable, less coloured, and, according to Hodgkin and Lister,* are destitute of those transverse striæ or lines observed by the microscope in ordinary muscular fibres. The chemical constitution of the middle coat of the arteries differs also from that of muscle, for it is less soluble in acetic acid, and more easily so in mineral acids, and it is believed by Berzelius and Young not to contain the animal principle, fibrine, peculiar to muscular flesh. Although we fully admit the importance of these observations as establishing anatomical and chemical distinctions between muscular substance and the texture of the middle coat of the arteries, they do not appear to us to warrant the conclusion too hastily deduced from them by some, that this coat cannot be irritable, or does not possess any of the same properties as muscle, the existence or non-existence of which must be ascertained principally by physiological evidence. For the transverse striæ cannot be considered as characteristic of all muscular fibres; and were we to reason in this way from the result of anatomical observations only, we should be necessitated to deny the irritability of various other textures, the contractility of which from stimulation or without it, is universally admitted, although anatomists have not yet detected muscular fibres in them.

The coats of the smaller arteries are generally believed to be proportionally thicker than those of the larger trunks, and John Hunter held the opinion that the yellow fibrous tissue exists in greatest quantity in the larger arteries; while the smaller vessels, considered more active, are composed of a substance more nearly allied to muscular fibre. The grounds upon which the latter opinion rests are upon the whole not very satisfactory; and it appears to be opposed by those instances in which, after the closure by ligature of the principal artery of a limb, the smaller collateral vessels which maintain the circulation, after undergoing a rapid enlargement, assume the structure and general appearance of the large arteries.

The irritability of the smaller arteries, now very generally admitted by physiologists, though it seems by some to have been inferred from analogy, and to have been rendered probable by Dr. Wilson Philip's observations on the effect of chemical stimuli in removing the dilated state of the capillaries in inflammation, was first distinctly proved experimentally by Dr. Thomson of Edinburgh,* who caused the arteries in the web of the frog's foot to contract powerfully by the application of mechanical irritation as well as by chemical stimuli. His experiments shewed that the nature of the contraction produced by stimulation of one of the smaller arteries varies considerably, occupying sometimes a greater or less space of the vessel, and being at other times confined to one place, sudden, and frequently so great as completely to stop the passage of blood. They also demonstrated the fact that the contraction of the small arteries does not follow immediately the application of the stimulus, as occurs in the voluntary muscles, but that a period of from one to three minutes elapses before the contraction begins, and that the vessel remains constricted for some time, and then returns to its original state, unless inflammation shall have occurred, in which case it dilates to a greater size than natural. The irritability of the small vessels has been fully established by experiments similar to those of Dr. Thomson, by Dr. Wilson Philip,† Dr. Hastings,‡ Kaltenbrunner,§ and Wedemeyer,§ the last of whom succeeded in causing the small arteries to contract by means of galvanic as well as of mechanical irritation. The constriction which follows the injection of styptic and irritating fluids into the arteries, observed by Hales|| in animals recently dead, and similar experiments by Wedemeyer, may be adduced as another proof of their irritability. The stoppage of hemorrhage from cuts of the small arteries and capillaries, assisted as it is by cold or irritating applications, may be regarded as the effect of the same property.

Contractions do not occur so readily or obviously in the large as in the very small arteries. Verschuir appears to have been the first who observed, in a manner not liable to fallacy, distinct contractions of the larger arteries to occur after the direct application of a stimulus. From an extended series of experiments upon this subject, described in his Inaugural Dissertation De Vi Arteriarum Contractili, Verschuir was led to adopt the opinion that the arteries are possessed of irritability, or contract in the same manner as muscles do from irritation; as he observed very obvious and powerful contractions to occur when, by means of a sharp point or chemical stimuli, he irritated the coats of the larger arteries of animals.

Haller, though considering the middle coat

* Appendix to the Transl. of Edwards's Work on the Influence of Physical Agents, &c. p. 443.

* Lect. on Inflammation. Edin. 1813.

† Introduct. to the second part of his work on Fever.

‡ Introduct. to his work on the Inflammation of the Mucous Membrane, &c.

§ Exper. circa statum Sang. et Vasor. in Inflammatione. Munich, 1826.

|| Untersuch. über den Kreislauf des Blutes, &c. Hannover, 1828. See also Koch in Meckel's Archiv. 1832, p. 121.

¶ Statical Essays, ii. p. 124.

of the arteries as of a muscular nature, was unsuccessful in producing obvious contractions in them. The repetition of the experiments of Verschuir by many others has been attended with very various results; some confirming his observations, others having entirely failed in producing any obvious contraction, or not being disposed to consider it of a muscular kind. Among the last may be mentioned Nysten, Bichat, Wedemeyer, and J. Müller.

It must be obvious that, laying aside the difference of opinion regarding the nature of the contractions when they are admitted to occur, in a question of this kind a positive result deserves more consideration than a negative one, provided the phenomena stated to have been observed are such as to be appreciable by all. Among the experiments favourable to the view that the large arteries are endowed with irritability, may be mentioned those described by Hastings,* and a series of unpublished observations by Dr. Thomson, to which we have access, which seem to prove in a very satisfactory manner the frequent occurrence of contractions in the larger arteries after stimulation; and to point out as a cause of the failure of some at least of the previous experiments, the long time which commonly elapses between the application of the stimulus and the occurrence of the contraction; together with the circumstances formerly remarked by Verschuir, that the contraction is not an invariable consequence of the stimulation, and that it occurs much more readily in some animals than in others.

According to Dr. Thomson the contraction of the larger arteries is in general not perceptible before from three to ten minutes after the application of the stimulus. When galvanism is used, the shocks need not be strong, but must be frequently repeated in order to induce contraction.

Many have remarked the gradual or sudden contraction of the trunks of arteries which have been laid bare in Man as well as in the lower animals. When exposed, an artery is sometimes equally contracted for some length along its tube; at other times its surface assumes a waved appearance from the occurrence of irregular contractions or alternate contractions and dilatations, and not unfrequently the coat of the artery is much constricted at one point only, as if a tight cord had been passed round it. Appearances of this kind, which seem to indicate very distinctly the possession of the property of irritability by the arteries, are well known to many surgeons; they were noted by Drs. Jones and Thomson, in the experiments upon which Dr. Jones's work on Hemorrhage was founded; and also by Dr. Parry, who nevertheless refuses to consider them as irritable contractions. At p. 74 of his work on the Powers of the Arteries, Dr. Parry, referring to Experiment 13th, says, "thus a very narrow ring of the carotid became, while it was under examination, contracted as if a small ligature had been half tightened around it." So also in Experiment 24th, he relates that a part of the carotid artery of a ewe was diminished by a third of its original diameter under exposure, after having been half an hour denuded, while the neighbouring parts had become rather dilated, and that while he was proceeding to measure one of these dilated portions, he "saw it shrink to nearly the same size as the constricted part." It appears to us manifest, that, whether these irregular diminutions of the diameter of the artery, obviously occasioned by a shortening of its fibres, are attributed to the exposure of the artery to the air, or the violence done during the dissection of it by the scalpel, they must equally be regarded as the consequence of stimulation of one kind or other, and are therefore of the nature of muscular contractions.

Hoffmann first noticed the contractions of the arteries from the application of acrid chemical stimuli to their coats; and it appears from numerous subsequent experiments, that contractions are more readily induced in this than in any other way. Were there no other proofs of the contractility of the arteries than those derived from the effect of chemical agents, we should not feel inclined to place much reliance on them, on account of the possibility of there having been induced a permanent alteration of the texture from chemical action; but the results of such experiments form an important confirmation of those which are performed with mechanical and galvanic irritation. We cannot, however, acquiesce in the opinion of Wedemeyer* and others who compare the distinct and well-marked contractions of particular parts of the arterial tubes, such as those above alluded to, to the general constriction of other textures, and more particularly to the shrinking of the skin which occurs from the influence of cold, passions of the mind, &c.

From these considerations we are induced to adopt the opinion that the contractions which under certain circumstances occur in the arteries resemble muscular contractions more nearly than any other vital phenomenon. The positive evidence of direct experiment obviously proves that the contractions in general follow the application of some stimulus to the artery; but these contractions differ from that of muscular parts chiefly in the length of time which elapses after the application of the stimulus before the change of size begins, in the slowness with which the contraction is succeeded by relaxation, and in the want of obvious correspondence between the force of the stimulus and the extent of contractions which follow it.

Besides the more marked contractions of parts of their tubes, the arteries are subject in various circumstances to undergo a slow and gradual diminution of their diameter throughout their whole length, which is considered by many physiologists to indicate the possession by them of a property of the nature of contractility different from irritability in its pheno-

* Inaug. Dissertat. Edin. 1817, et loc. cit. See also Hunter on the Muscularity of the Arteries, Edin. Med. and Surg. Journ. xxii. p. 256.

* Loc. cit.

mena and the causes which call it into action. A power of a similar kind, to which the name of Tonicity is applied, is believed to reside in the voluntary muscles.*

The experiments and observations generally stated in proof of the tonic power of arteries are the following: —

1. When a ligature is placed upon an artery of a living animal, the part of the artery beyond the ligature becomes gradually smaller, and is emptied to a certain degree, if not completely, of the blood it contained.

2. When a part of an artery in a living animal is isolated from other organs by means of two ligatures and punctured, the blood issues from the orifice, and the enclosed portion of artery is nearly completely emptied of its contents.

3. The empty condition of the arteries generally found after death is believed to be, in part at least, produced by a slow contraction of the whole of the large arterial tubes; for it has been observed, that some hours after death the arteries are much diminished in size, and this occasionally to such an extent as to be rendered impervious, as was observed in the umbilical arteries of the navel string by John Hunter† and others.

4. It has been shewn by Poiseuille‡ that when a portion of an artery from an animal recently dead, and one from an animal that has been dead for some days, are distended with an equal force, the portion of the artery from the recently dead animal becomes more contracted after the distending force is removed than the other one.

5. In the last place, when a large artery is divided, the cut extremities frequently become so completely constricted as wholly to prevent the issue of blood, and this kind of contraction is well known to occur in a greater degree after laceration of an artery than after division by the knife: hence the less danger to be apprehended from hemorrhage in lacerated than in incised wounds; and thence the possibility of producing the closure of one of the larger arteries by the mere compression or torsion of its cut end.

In the three last-mentioned proofs of tonicity the contraction of the artery followed the application of some kind of irritation; for the exposed artery was dissected out by the scalpel, and ligatures were tightened round it, the coats of the artery were stimulated by distension in Poiseuille's experiment, and in the twisting or torsion as well as in the division of an artery by laceration or cutting there is always an irritation applied to the contracting part. The tonicity or tonic contractility therefore was in some of these instances first called into operation and in others increased by irritation, and ought not therefore to be distinguished from irritability as regards its cause, but only as relates to its phenomena.

The evacuation of the blood from arteries beyond the place at which they have been tied in the living body, and the contraction of arteries which takes place in the dead body, as well as the rigidity of muscles soon after death, or their retraction when divided in the living body, all seem to indicate a tendency in irritable parts to undergo a slow and continued contraction during the persistance of their vital powers. This tendency to contraction seems to differ from the shortening and subsequent relaxation which are the more or less immediate effects of stimulation in truly irritable parts, and it seems to be more dependent upon the removal of the forces by which the parts in which it occurs are kept in a state of distension than upon any other cause.

It is obviously in consequence of this tendency to contract when not distended by a force from within, that the arteries are always nearly accommodated to the quantity of blood contained in them. But while we are constrained to admit the existence of the peculiar slow contractile power in arteries appropriately denominated tonicity, we would caution the accurate physiologist against considering as the effect of this property rather than of irritability any of those contractions of the arterial tubes which are induced or increased by mechanical, galvanic, or other stimuli.

e. Influence of the vital powers of the arteries on the circulation.—Let us now inquire in what manner the flow of the blood is influenced by the irritability and tonicity of the arteries.

Some of those who have regarded the arteries as contributing by their active powers to propel the blood have conceived it sufficient for them to prove that there is a necessity for some additional force in the circulation besides that of the heart, in consequence of the total expenditure of the heart's force from the windings of the small vessels, the friction of the blood against the side, and other resistances to be overcome in the capillary system. This expenditure of the heart's power admitted by many on insufficient grounds has been very generally overrated. Although the causes just mentioned may diminish to a certain extent the propelling power of the heart, there are various very simple experiments which shew that the heart's action is propagated with a propelling effect through the whole vascular system, so as to act in the extreme vessels and veins.

In the first place, Haller, Spallanzani, Thomson, and many others have observed in the transparent parts of animals that the impulse of the heart is transmitted to the very ends of the small arteries, which may be less than $\frac{1}{500}$th part of an inch in diameter, and that in some states of the circulation the impulse of the heart is continued on through the capillary vessels and into the commencements of the veins. The fact that this generally occurs when the action of the heart is weakened, and when the vessels are consequently not sufficiently distended by its impulse to react by their elasticity and convert the remitting into a uniform force, is a distinct proof that in the natural state of the circulation a greater pro-

* Parry, loc. citat.
† On the Blood and on Inflammation.
‡ Magendie's Journ. vol. viii.

portion of the force of the heart must be transmitted through the blood to the capillaries, and must act through them upon the column of blood returning in the veins.

From the same experiments it has appeared that in general the instant any obstruction prevents the action of the heart from being propagated onwards in the arteries, the progressive current of the blood in the small vessels becomes slower and soon ceases, any motion which goes on afterwards being quite of a different kind from that occurring in the natural circulation.

An experiment performed by M. Magendie, and formerly referred to, also affords a very satisfactory proof that the heart's force acts in propelling the blood through the whole vascular system. M. Magendie dissected the femoral artery and vein separate from the neighbouring parts, and passing a ligature under them tightened it round the whole limb, excepting the two principal bloodvessels, through which the blood was allowed to flow freely. He was thus enabled to shew that the flow of blood from an orifice in the vein was immediately dependent on the force of the heart acting through the artery, as it was suddenly diminished and soon completely ceased the instant that the latter vessel was obstructed, and became more or less rapid according as it was more or less compressed. We would further remark that the experiments of Hales and Poiseuille, more particularly the latter, have shewn that there is little if any difference in the force of the blood in arteries of very different size.

On the other hand, it appears to us sufficiently clear that the occurrence of any general contraction of the coats of the arteries would have the effect of opposing an obstacle to rather than of assisting the progress of the blood in the arteries, just in proportion to the degree of the force of the heart, which would necessarily be expended in dilating them to the required size, in order to allow of the free transmission of the blood by them; and as, according to the commonly received opinion, the contractile powers are greater in the smaller than in the larger arteries, the operation of this contraction would be much the same as the diminution of the aperture through which blood flows from an inorganic tube, and would thus cause a still greater obstruction to the flow of blood than a general contraction. It is only on the supposition that the arteries undergo an undulatory or vermicular contraction, proceeding from the larger to the smaller branches, that this contractile force can be believed to contribute to the progressive motion of the blood, because then it might be conceived to assist the elasticity of the arterial parietes in propagating the force of the heart along the column of contained blood, and even augment this force by an additional power. But we would remark that no such vermicular action has been ascertained to occur by any observations or experiments with which we are acquainted; that in artificial injection of fluids into the large arteries of dead animals a force of a few pounds is found to be sufficient to propel these fluids, when not of an irritating kind, from the arteries into the veins; and that it follows from the direct experiments of many, more particularly those of Hales, Poiseuille, and Magendie, that the action of the heart, transmitted by the elastic arteries, is the only cause operating in the progressive propulsion of the blood in arteries of such a size as to admit of the force of the blood being measured in them.

In asserting, however, that a general contraction of this kind, if it occurred in the vascular system, would upon the whole obstruct or retard rather than assist the progressive motion of the blood in the arteries, we would not be supposed to deny that the vital powers of the arteries may modify very considerably the distribution of blood to different parts, for it is manifest that an increased action occurring in one part of an artery may hinder the blood from being transmitted in its usual quantity into a neighbouring part, while a dilated state of an artery or its branches, or, if we please to call it so, a diminished action or greater weakness of resistance of the coats of the artery considered relatively to the powers of propulsion operating through it, may occasion the flow of a greater quantity of blood to a part, as occurs in local inflammations. Among the many indirect arguments adduced on both sides of this question may be mentioned the following. In the first place, the fact that in the lowest classes of animals, as in Vermes and Insects, which have no proper heart, the bloodvessels propel the blood by their contractile power, and that in some of the higher animals, particularly Reptiles and Fishes, parts of the vascular system, as the bulb of the aorta, a considerable portion of this vessel, parts of the veins, and so on, are distinctly contractile, and assist the powers of the heart, are adduced as proofs from analogy that the arteries in warm-blooded animals may have the same power and perform the same function. Now it may be answered to this, that the circumstance of the lowest classes of animals having no proper heart is the final cause of or an obvious reason for the greater contractility of these vessels; and in the second place, that no rythmic contraction is observed to occur in the arteries of warm-blooded animals of the same nature as that observed by Haller, Spallanzani, M. Hall, and others in the bulb of the aorta and other parts of the vascular system of cold-blooded Vertebrata. For similar reasons we are not inclined to attach much importance to the argument in favour of the independent powers of the arteries deduced from the alleged occurrence of circulation in acephalous fœtuses, in all of which the proper muscular heart seems to be wanting; for although the distribution of the vessels in these fœtuses has been sufficiently accurately determined, the nature of the circulation which occurs in them is a subject involved in the greatest obscurity. There seems good reason to doubt that such fœtuses have ever existed alone in the uterus, in which case their vessels may, as is known in many of them to have occurred, have been connected with those of a perfect fœtus; and even were this not the case, the absence of the heart might be attended in these malformed productions with an unusual development of muscular power in parts of the vascular system.*

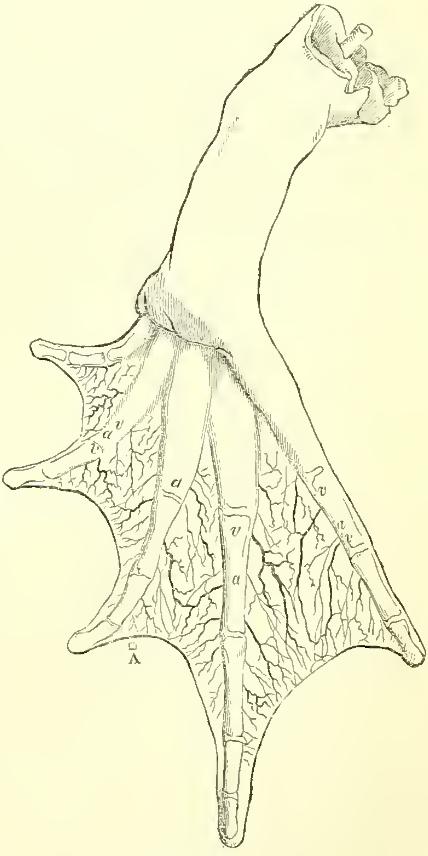
In conclusion, we may remark that the argument drawn from the occurrence of circulation apparently little impaired through arteries which have been completely ossified for a considerable time, seems to be very much in favour of the view we have taken that the heart alone is the cause of the progressive flow of blood through the arterial tubes.

3. *Phenomena of the capillary circulation.*—The phenomena of the passage of the blood from the terminations of the arteries into the commencement of the veins through the capillary vessels, are highly interesting and important in many points of view, for the immediate respiratory change which the venous blood undergoes in the pulmonary vessels, and all those alterations of composition which accompany nutrition, growth, secretion, and other organic processes connected with the systemic vessels, occur in the smallest ramifications of the pulmonic and systemic circulation, and the morbid state of inflammation as well as the various pathological changes which occur as its consequences are intimately connected with an altered condition of the capillary system.

a. Structure and distribution of the capillary vessels.—The name of capillary is generally given to all those minute vessels which form the means of communication between the small ramifications of the arteries and veins; but there is some difference in the opinion of anatomists and physiologists as to how much of the vascular system ought to be included under the division of the capillary vessels. Some, adhering to the strict meaning of the term, apply it to all the small vessels whatsoever under a certain size; others hold that between the extremities of the arteries and veins there is always situated a series of minute tubes of nearly equal size in their whole length, and not ramifying like the arteries or veins, which constitute a system of vessels distinct from the others in their structure, distribution, and properties, to which the name of capillary ought to be restricted.† The last view appears to us to be founded in a partial acquaintance with the system of minute vessels, for though it may be true that in some parts of animals the capillaries have obviously the structure above described, and seem to form a system of vessels apart from the smaller arteries and veins, yet this is by no means the case in other textures; and we think that the more extensive observation of the structure of these vessels in various parts will shew that in the greater number, as is well ascertained to exist in many, the smaller arteries pass into veins quite in a gradual manner, the ramifications of each class of vessel becoming more and more minute until they meet, the two kinds of vessel presenting no difference of character other than the change of direction assumed by the moving blood, which enables us to say with certainty where the artery terminates, and at what point the vein begins, and affording thus no reason to consider the continuous tube by which they join as different in structure from either the minute artery or vein. While we acknowledge therefore the importance of the observations which point out the existence of capillary vessels of a uniform size in some textures, we think it necessary to retain the name of capillary as applied to all the minute vessels, both for the reason that the communicating vessels are not every where of the same kind, and that from the use already made of the term by physiological writers its meaning will thus be more easily understood.

The vessels which lead from arteries to veins are of very various sizes, some admitting only one globule at once, others being so large as to allow of the passage of three, four, or even a greater number of red globules together. In tracing with the microscope the motion of the minute streams of blood as they pass through the capillary vessels, the eye is guided by the

Fig. 330.



Frog's foot.

* See the Researches of Elben, Tiedemann, Breschet, and others on Acephalous Monsters.

† Dr. Marshall Hall's Essay on the Circulation of the Blood, Lond. 1831. Dr. James Black's Short Inquiry into the Capillary Circulation, Lond. 1825.

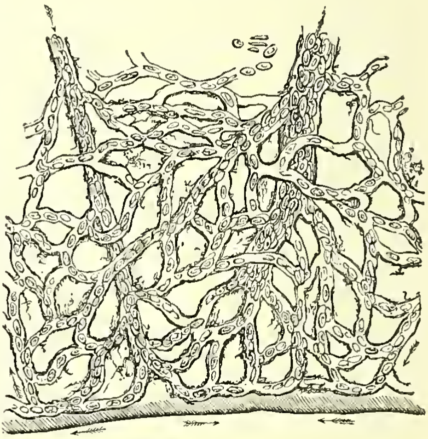
motions of the red globules principally, for it is very rarely indeed that the current of fluid which carries the globules along can be recognized in the ordinary modes of observation.

The capillary circulation is most easily seen in cold-blooded and in young animals, both on account of the large size of the red globules and the small number of the vessels. Since the first discovery of the capillary circulation by Malpighi, the transparent web between the toes of the hind feet of the frog has been universally adopted as the most convenient situation for observing this beautiful spectacle with transmitted light. The fins and tail of fishes, the tail of the larva of the Frog and Newt, the external gills of the same animals as well as of cartilaginous fishes, the mesentery of the Frog or of small warm-blooded animals, the wing of the Bat, the lungs and urinary bladder of Reptiles, the liver of the Frog and Newt, the membranes of the incubated egg, the yolk of the Skate's egg, are all situations favourable for the observation of the capillary circulation. The capillary circulation has been viewed in only a small number of warm-blooded animals, and in very few of their textures; but the minute injection with coloured fluids of all parts of the bodies of Quadrupeds and of Man leaves little doubt that in them also, whatever varieties there may be in the size, number, and distribution of the small vessels, the blood passes in every organ from the small arteries into the returning veins by minute continuous tubes of the same nature as those more easily observed in the situations above-mentioned.

Some are inclined to consider the minutest or proper capillary vessels as destitute of vascular parietes, and consisting of mere passages through the texture of the organ in which they exist without any lining membrane. This opinion is founded on the impossibility of seeing the coats of the vessels, the rapidity with which new capillaries may be developed, and some other circumstances. The extreme degree of minuteness of the smallest capillary vessels must render futile any attempts to decide this question by direct observation. Besides the general analogy between the larger and smaller vessels, there are several circumstances known which seem to be strongly in favour of the view that the capillaries do not differ in this respect from other vessels. 1st, It is allowable to suppose that the active properties of the capillary vessels belong to parieties as in the larger vessels. 2d, In many transparent parts of animals in which the terminal arteries and veins do not diminish to a very small size, the coats of the vessel may be seen with the microscope, as in the external gills of the Amphibia, and in the vascular rete of the ear of birds and reptiles, in which the capillary vessels may, after having been injected, be separated from the neighbouring soft texture. 3d, The conversion of small into larger vessels with visible coats in those instances in which the course of blood through the vessels of a part has undergone an alteration, is in favour of the previous existence of parietes in the smaller vessels. And 4th, The constant and regular distribution of the minutest vessels in many parts of animals appears to support the same view. The argument in favour of the non-existence of capillary parietes deduced from the alleged facility with which the blood occasionally passes out of the regular vessels and takes an irregular and indeterminate course through the non-vascular parenchyma of an organ, we believe to be founded, in some instances, in peculiarities belonging to a few parts only, and in others in inaccurate observation; for in almost all those situations in which the capillary circulation may be seen with ease and distinctness, the constancy of the minute passages which the blood permeates is undoubted.

From the more accurate means of making minute anatomical researches that have been introduced in modern times, the existence of serous, exhalent, and white vessels has become a matter of great doubt, for vessels of this description which do not admit the red globules and liquor sanguinis together cannot be made obvious to the senses by the most delicate injections or dissections; and the observation of the capillary circulation in the transparent parts of animals affords the most convincing proof that the smaller arteries have no visible terminations excepting in the capillaries and small veins. In observing attentively the web of the frog's foot and other

Fig. 331.



Capillaries in the web of the Frog's foot magnified.

transparent parts in which the motion of the blood is easily seen, we occasionally see globules of blood run into passages of the tissue which we did not perceive before; but a sufficient acquaintance with the structure and distribution of the smallest of the capillaries in these situations will soon convince the careful observer that the vessels into which the blood was seen to pass, apparently for the first time, existed fully formed before, that the fluid part of the blood passed in part through them, and that the stoppage of the red particles was to a great measure dependent on partial or local impediments. The compression of one of the small arteries, for instance, will frequently, after causing oscillation of the globules of the blood in the smallest capillaries, be followed by the disappearance of some of them; but in a very short time, or when the obstruction is removed, the blood regains its former velocity and force, and flows into exactly the same passages as before.

The notion that the smaller vessels are continuous with the smaller lymphatics, and more especially with the excretory ducts of glands, seems to be fully disproved by the accurate researches of Malpighi, Mascagni, Panizza, Müller, and Weber, which have shewn that the lymphatic vessels originate at all parts of the body by a plexus of tubes every where closed, and that the excretory ducts of secretory organs begin always by shut ends.

We believe it to be satisfactorily shewn that in the whitest of the textures (with the exception perhaps of the cornea and crystalline lens), there is no necessity for the supposition of vessels admitting the fluid parts only of the blood, or of serous vessels, as they have been termed; and that in all of them there exist small bloodvessels which admit very fine rows of globules in their accustomed proportion to the fluid part of the blood: for many textures which appear perfectly white or colourless, or only slightly yellow when viewed with the naked eye, are found, when examined with the microscope, to have small vessels carrying blood globules through them. Spallanzani and others shewed that very small vessels taken singly or seen in very thin layers have almost no perceptible colour; and it is a well known fact that, in what are called the red textures, the colour (as of muscle for instance) is not exclusively dependent upon the quantity of red blood in them. It is difficult, indeed, to conceive how the circulation of the blood could be carried on at all, or how the red particles of the blood could ever be returned to the heart were the globules to be retained in the larger vessels, and all the white textures to admit only the fluid parts of the blood.

In adopting the opinion that the arteries terminate always by direct continuity of tube in the veins, and that no other visible passages are connected with the minute vessels, we must suppose that the various interchanges of materials occurring between the blood and the organized textures or foreign matters, as in nutrition, secretion, respiration, transpiration, &c. must take place by some process of organic transudation through invisible apertures of the minute vessels.

b. Properties of the capillary vessels and influence on the circulation.—From the experiments already referred to, it is apparent that the smaller arteries, so long as they can be distinguished from other vessels, are capable of being excited to contraction by the application of a stimulus; but we have no means of shewing this with regard to the minutest capillary vessels, because we can scarcely apply any stimulation to them without affectin some of the smaller arteries at the same time. When it is said, for example, that the capillary vessels are irritable, because the application of ammonia or spirits of wine causes them to become smaller, it is difficult to determine how far this appearance of diminished size in the capillaries depends on their receiving less blood, in consequence of the contraction of the small arteries leading to them or upon the less size of these vessels themselves. In the experiments of Dr. Thomson and others, however, the application of salt and other stimuli exciting inflammation have appeared to dilate even the smallest capillary vessels, and such a dilatation can scarcely be considered as indicating any thing else than a less power of resistance in these vessels; and when the application of ammonia or spirit of wine restores such dilated capillaries to their natural condition, we do not see that any other natural inference can be drawn from this fact than that the capillaries have been contracted by the influence of these stimuli; for the contraction of the small arteries alone, although it might restore the lost velocity of the blood, would not diminish the capillaries to their former size. This general diminution of size ought however to be carefully distinguished from the more marked and local contractions of true arteries.

The velocity of the blood is quite uniform in the capillaries of the adult animal in the natural condition of the circulation. There is reason to believe the capillary vessels to be highly elastic, and to have the effect of completing the change which is begun by the arteries, viz. that of equalizing the force of the heart transmitted through the blood. We do not, in observing attentively the capillary vessels, ever perceive any motions of alternate dilatation and contraction of their sides. The blood flows through them as through small glass tubes; and if they act by other powers than by their elasticity alone, this action must be of so slow a kind as not to be perceptible. There can be no doubt that any action of contraction occurring in the capillary vessels, whether alternating with dilatation or not, could have no effect excepting that of obstructing the passage of blood through them. It would act upon the contents of the arterial system much in the same way as the diminution of the aperture at the end of a rigid tube would affect the flow of fluid through it, that is, either a less quantity of blood would pass through the capillary vessels in consequence of their less size, or a greater portion of the heart's force would be expended in dilating these vessels to a sufficient extent.

The principal reasons which we feel inclined to adduce for believing that the heart's action is continued onwards through the capillaries, and is sufficient to return the blood through the veins back as far as the heart itself, are the following:—1. That in an animal recently killed a very small force only is requisite to cause bland fluids to follow the course of the blood, provided the injection be made before the tonic contraction has had time to constrict the vessels. 2. The experiments of Hales and Wedemeyer shewing that, according to the more or less stimulating character of the fluids, their passage through the vessels was more or less easy. 3. The experiments shewing that, in an animal which has been dead for some time, steeping of the body in warm water, and the injection of warm water into the vessels, so as to clear the passage through them, puts the vessels in such a condition that a force of a few pounds is sufficient to effect the propulsion of fluids through them. 4. The observations of Haller, Spallanzani, Magendie, and others, that all regular progressive motion of blood in a vein, or the issue of blood from an orifice in a vein, ceases very soon after the heart's action is suspended, or when any obstacle prevents its force being communicated to the blood in the veins. 5. The observations of Spallanzani, Thomson, and others, that the impulses of the heart are visibly continued on through the small arteries and capillaries, and even into the veins in some states of the circulation. This phenomenon is most apparent at the time when the action of the heart is weak, and in such states of the circulation this remittent flow of the blood may be converted into a merely oscillatory movement without any regular progression by the gradual increase of the pressure applied to the artery which supplies the blood to the capillary vessels under observation; a fact which shews distinctly on the one hand that the force of the heart is continued on through the capillaries, and on the other that when a resistance is opposed to the progress of the action of the heart through the arteries, no other force then operates sufficient to cause a continued and progressive motion of the blood.

But, although the small vessels do not contribute by their active contraction to propel the blood through them, or although they do not as a whole assist the force of the heart, it is yet very apparent that they have the power of modifying in a remarkable manner the flow of blood in particular parts. Among the circumstances which prove this power of the small vessels to modify the circulation may be mentioned the various instances in which there occur local determinations to particular parts, unaccompanied by any change in the action of the heart or in the general circulation. 1. The act of blushing and erection, or the reverse actions of paleness, collapse, &c. which seem to depend, in most instances at least, on some change in the terminal vessels. 2. Inflammations or hemorrhages confined to a particular part of the body. 3. The increase or decrease of secretions from glands, periodical or instantaneous. 4. The increased size of the vessels of the uterus during pregnancy, of the mammæ after child-birth, &c. 5. The enlargement of bloodvessels in new growths, tumours, &c. 6. The enlargement of collateral anastomosing vessels, after the closure of the principal trunk of a limb. And, 7. The unequal growth or development of different parts of the fœtus. Although we do not understand the nature of the change in the vessels which accompanies these partial distributions of blood to particular parts, yet they all sufficiently demonstrate that while the heart's action remains the same, the quantity of blood sent to particular parts must have been modified by some action of the vessels themselves.

There are some physiologists, however, who hold the opinion that the motion of the blood is promoted in some way or other (they do not sufficiently clearly explain how) by powers acting on it during its passage through the capillary vessels; and there are a few who have gone so far as to suppose that the heart drives the blood only as far as the capillaries, from whence it is propelled onwards into the veins by powers originating in the small vessels themselves. These opinions have been supported chiefly by arguments drawn from the facts already mentioned as illustrating the power of the small vessels to modify the circulation or to cause local variations in the distribution of the blood, as also on the following grounds, which are ably stated in a supplement to his Outlines of Physiology,* recently published by Professor Alison, of Edinburgh, who is one of those who have more lately adopted this opinion, and by Dr. Black in an ingenious essay on the capillary circulation.†

Besides the analogical argument drawn from the lower animals having a circulation of fluids without any heart, and the supposed unaided circulation in acardiac fœtuses, it is stated that—

1. After the heart of the frog or such cold-blooded animals has been cut out, or a ligature passed round the aorta, some motion of the blood still continues to occur for a few minutes in the small vessels; and it is farther stated, that this motion is influenced by heat, by certain applications to the web of the frog's foot, and the state of the nervous system.‡

2. That while the circulation is going on with its usual freedom, the direction and velocity of the flow of blood are subject to sudden or rapid changes which do not admit of being accounted for simply by contractions of the vessels.

3. That the blood when out of the vessels, immediately after it has been drawn, or when extravasated in the textures, performs motions which seem to belong to itself or are spontaneous.§

4. That the passage of the blood through the capillary vessels of the lungs is immediately influenced by the chemical change of the venous blood into arterial, for its velocity is diminished as soon as this change does not occur.||

5. That the remoteness of the capillaries of the vena portæ of the liver from the heart ren-

* Outlines of Physiology, Supplement to 2d edit. Edin. 1836.

† London, 1825.

‡ Haller, Guillot, Leuret and Wilson Philip, Marshall Hall, and others.

§ Kielmeyer, Treviranus, Carus, Czermack, Œsterreicher, and Schultz.

|| Dr. Alison, loc. cit.

ders probable the existence in them of some power capable of propelling the blood independently of the heart's action.

6. That in the production of new vessels which occurs in adhesion or granulation, the new blood executes oscillatory motions in the rudimentary vessels while in the act of forming, before these parts of vessels are connected with the previously existing branches through which the heart propels the blood; and this is said also to occur in the formation of new vessels in natural growth.*

7. That in the formation of the vascular area of the incubated egg the blood moves in part through the veins and small vessels before it is impelled by the action of the heart.†

We would remark, regarding the oscillatory and irregular motions described by Haller and others as occurring in the small vessels of the web after removal of the heart or ligature of the aorta, that we believe some of these to be caused by the elasticity of both the arteries and veins, and others to be occasioned by the gradual or tonic contractions which take place in the arteries after death:‡ they occurred in all Haller's observations, but in Spallanzani's only when the apparatus of hooks constantly employed by Haller was applied; and so far as we have ourselves been able to observe them, we have always found them influenced by very slight changes. When one of the small vessels is obstructed they cease altogether, which ought not to be the case were they dependent upon powers belonging to the capillaries or the blood in them. Some varieties in the velocity and direction of the blood in the smaller vessels we have reason, from our own observations, to attribute to the same causes, and we think it consonant with such a supposition that heat or other agents influencing the contraction of arteries should influence these irregular motions. The oscillations of blood in parts of vessels which are in the process of formation in adhesions and granulations, or in natural growth, we have not yet been able to observe so clearly as to be certain that we were not deceived; but, even supposing them to have been satisfactorily proved to occur, we should be inclined to doubt the possibility of ascertaining with accuracy that these portions of vessel are entirely shut off from all communication with other vessels, so as that no impulse could be transmitted from the heart to them. The necessity of some change in the tissue of organs or of organizable lymph, in which new vessels are about to be formed before the propulsion of the blood into the new loop of vessel seems sufficiently obvious, but it does not appear to be as yet satisfactorily shewn that the motion of blood in the new vessels is independent of a propulsion received from the heart. Again we consider it as ascertained that the heart of the chick acts just as soon as any motion of fluids can be seen on the vascular area of the yolk; and though it may be admitted that a certain change of place in the particles of the yolk is necessary in the new combinations which occur during the developmentof the forming parts from its substance, yet such a change or motion must be quite of an insensible kind and not in any degree analogous to the continued stream of circulating blood through the vessels.

The stagnation of venous blood in the capillaries of the lungs is certainly a most remarkable and inexplicable phenomenon, but if from analogy any weight is to be attached to observations made upon the frog, it may be stated that the flow of blood through the lungs seems as immediately dependent on the heart's action as that through the system. The portal circulation is not more remarkable in respect of its isolation from the heart than the systemic circulation of fishes, in which animals the capillaries of the gills intervene between the heart and the systemic aorta; and without any distinct contraction of that vessel, the circulation of the blood in the systemic capillaries as well as in the gills is very manifestly maintained chiefly, if not solely, by the action of the heart. We do not feel inclined to attach any importance to the alleged motions of the globules of the blood out of the vessels, for we have never been able to see any such indicating different powers from those which produce currents in inorganic fluids, and some of the observations upon which the statement is founded have been shewn to be erroneous.

We think it unnecessary to do more than merely to allude to some of the very many attempts that have been made to account for independent motion of blood in the capillaries, or what have been termed the theories of the capillary circulation.

All that we know of capillary attraction militates against the possibility of its being the means of causing a progressive motion of fluids, such as that which occurs in plants and animals. Those who have attributed the motions of fluids in the living body to endosmosis or a principle of organic transudation, have failed in pointing out in the bloodvessels the conditions necessary for the occurrence of a motion proceeding from an action of this description. The electrical theory is defective in this essential point, that no difference in the electrical condition of the arterial and venous blood has been shewn, and that the same cause to which the motion of the capillaries of the systemic arteries is ascribed ought to retard the passage of blood in the pulmonary capillaries, the relations of the two kinds of blood being there reversed. The opinion that the motion of the blood in the vessels is analogous to those currents of fluids which take place in contact with the surfaces of various parts of animals, which are almost always connected with ciliary mo-

* Dœllinger, Journ. des Progrès, &c. vol. ix. Kaltenbrunner, loc. cit. Baumgärtner, Beobacht. über die Nerven und das Blut. Freiburg. 1830.

† [Dr. Tanchose suggests as a cause for the motion of the blood in the capillaries, the ceaseless removal of particles from the blood to supply materials to the various secretions, &c. a constant tendency to a vacuum being thereby produced. Acad. des Sciences, Séances d'Avril, 1833.—Ed.]

‡ See Marshall Hall's Essay, p. 95; and also Black's Inquiry, for judicious remarks upon these oscillations.

tions, and are described under the head of Cilia in this Cyclopædia, isdefective in so far as neither cilia nor any power of exciting currents has yet been shewn to exist in the interior of the bloodvessels, and they have been examined in circumstances in which we conceive they would have been seen had they been present. In fine we cannot see how any power of spontaneous motion belonging to the blood itself could be a cause of progressive motion of that fluid, unless the direction of the motion were determined by the solid textures containing the blood, and in this case the same objections would apply to this explanation of the cause of motion as to the one to which allusion has just been made; and besides, the evidence of spontaneous motions of the blood appears upon the whole of a very unsatisfactory kind.

From these considerations we find ourselves constrained to hold the opinion that, however great the power which the capillary vessels possess of modifying the distribution of the blood, there is not reason to believe that they contribute as a whole to its progressive motion.

4. *Phenomena of the venous circulation.*—In the natural state of the circulation the flow of the blood is nearly quite uniform in the veins, as may be seen when a vein is opened in the common operation of venesection. In those rare instances in which the flow from a vein is accelerated after each beat of the heart, in the same way as the arterial jet, it may be supposed either that the intermitting impulses of the heart are, from some circumstance or other, transmitted more freely and to a greater distance than usual through the capillary vessels, as is known occasionally to happen, or, what is more probable, that the larger branch of the vein receives the successive impulses directly from neighbouring large arteries, which are more than usually dilatable.

As the size of the veins is generally greater than that of the corresponding arteries at the same distance from the heart, and as they are also more numerous, the velocity of blood is less in these parts of the veins than of the arteries; and as the whole venous system contains considerably more blood than the arterial, the velocity of the blood taken as a whole must be less in the veins than in the arteries. The same quantity of blood must be brought by the venæ cavæ to the right auricle as issues from the left ventricle, (making allowance for the expenditure by secretions, &c.) and consequently the velocity of the blood entering and of that issuing from the heart must be equal. Again, the velocity of the blood must be gradually on the increase in its progress from the small to the larger veins, because the capacity of the vessels into which it flows is gradually becoming less.

In the systemic veins, excepting the venæ portæ, the direction of the flow of blood is determined by the structure of the valves, which permit of the return of blood from the extremities of the veins towards the heart, but oppose, by the filling of their pouches and the apposition of their free edges, a complete obstacle to the reflux of the blood in another direction.

The principal cause of the progressive flow of the blood in the veins is unquestionably the force of impulsion of the heart continued through the arteries and small vessels, as appears from the flow from the remote part of an opened vein and the simple experiments of Hales, Magendie, and Poiseuille already referred to. Hales ascertained, by introducing tubes into the larger veins of the horse, that the pressure on the blood from behind, or *vis à tergo*, is sufficient to raise the blood in the tube to a considerable height above the level of the heart, and is consequently more than sufficient to return the blood to the auricle of the heart. The blood did not, in Hales' experiments, in general at first rise in the tube connected with a vein more than six inches, but this he shewed to proceed from the easy escape of the blood by lateral communicating vessels, for when the other large veins were tied, or when they became fully distended with blood, that fluid sometimes rose in the tube connected with a large vein to a height of three or four feet. M. Poiseuille* demonstrated, in a still more satisfactory manner, the action of the pressure of the heart on the blood in the veins by means of the bent tube with which he measured the pressure of the arterial blood: and this fact is proved in an equally convincing manner by Magendie's experiment of isolating the principal artery and vein from the other parts of the limb of an animal, in which it was found that the flow of blood from the vein is immediately stopped by pressure or ligature of the artery. It is scarcely necessary, in order to obtain a proof of this fact, to have recourse to the vivisection of animals, for in common bleeding from the arm, the flow of blood from the vein will be found to be immediately influenced by the state of the artery, and even without the division of a vein, it is easy to observe the action of this force of impulsion which drives the blood onwards towards the heart in any of the superficial veins of the arm by the application of external pressure, a mode of illustration successfully adopted by Harvey in his explanation of the course of the blood. These very simple experiments are looked upon by some as quite sufficient to demonstrate the proposition that the blood is moved in the veins by an impulsion from behind, and that that impulsion is derived from the action of the heart; while others, not satisfied with this explanation, have endeavoured to point out additional forces as contributing to the progressive motion of the blood in the veins.

The larger veins are, like the arteries, highly elastic, and they are generally regarded as stronger proportionally to the thickness of their coats than the arteries. This elasticity belongs chiefly to the external cellular coat, for a middle fibrous coat is not apparent in most of the larger healthy veins, and in those rarer instances in which it is apparent, it is very much thinner than in the arteries. The smaller or capillary veins appear also to be possessed of some degree of irritability, for they have been

* Magendie's Journ. vol. x.

seen to contract on the application of a stimulus in the web of the frog's foot by Drs. Thomson and Hastings. This, however, occurs much more rarely than the contraction of the small arteries. It has been remarked that in some animals muscular fibres are prolonged from the auricle upon the adjoining part of the vena cava; and Spallanzani, M. Hall, Flourens,* and others have recorded the fact of the rythmic contraction of parts of the great veins adjoining the auricles. But, excepting in these situations and in the caudal heart, observed by M. Hall in the Eel, muscularity of the veins cannot be considered as having any effect in promoting the flow of the blood in these vessels.

The progressive motion of the venous blood takes place with little force, and is therefore subject to considerable variations from external pressure. Thus the flow of the blood may be much accelerated by raising a limb, or retarded by keeping it in the depending posture from the mere effect of gravitation, and the common practice of making a person who is bled in the arm call the muscles of the arm into action during the operation, is a sufficient proof that the pressure of the muscles may be the means of accelerating in a considerable degree the venous circulation,—an effect obviously dependent on the disposition of the valves. Gravitation or muscular action are, however, only occasional causes of the acceleration of the flow of blood in the veins, and both, but particularly gravitation, may in some instances offer an obstacle to its progress.

There are some physiologists who believe the blood to be drawn through the veins towards the heart by a power of suction which operates from the side of the heart or chest. The remarks we have already made in treating of the arterial and capillary circulations render it unnecessary for us to revert in this place to the arguments employed by those who have supported the above view, merely on account of their belief in the inadequacy of the heart's force to maintain the complete circulation; we shall only now state the direct experiments or reasonings by which it has been attempted to be proved that a *vis à fronte* or suction power draws the blood towards the centre of the circulation. We have already, in a former part of this article, stated our reasons for believing that the elastic power of the heart itself is not attended with any production of an appreciable force sufficient to draw the blood into its interior.

The facts which relate to the supposition that the chest or lungs become, during their motions in respiration, the source of a suction power which acts on the venous blood may be suitably considered under the first part of the fourth division of this article, viz.

IV. The relation of the circulation to other functions.

1. *Respiration.*—Of the opinions of those who attribute the suction of the blood through the veins to powers within the chest, there are chiefly two which have of late years attracted attention,—those namely of Dr. Carson of Liverpool,* and of the late Sir David Barry.†

According to Dr. Carson the lungs are of a highly elastic nature, and are kept in a state of forced distension by the pressure of the atmosphere which enters them when the chest dilates. The lungs would collapse or fall away from the walls of the chest but for the force with which they are distended, and there is thus a tendency to the production of a vacuum within the chest or to a diminution of the pressure on the exterior of the heart, in consequence of which the blood is forced or drawn into the heart and chest on the same principle that fluid enters the mouth in the act of sucking.

According to Sir D. Barry, at each inspiration of air into the chest the lungs are not sufficiently expanded to fill the whole of the chest, or there is, in consequence of the expansion of the walls of the chest, a less pressure within the chest than on its exterior, and the blood is propelled through the veins communicating with the heart by the external atmospheric pressure.

Neither Dr. Carson nor Sir D. Barry state, in a sufficiently explicit manner, how much of the force impelling the blood through the veins they conceive to be of the nature of suction: they both admit that the greatest part of this force belongs to the heart or *vis à tergo*, but they yet state distinctly their belief that the suction power is an important cause of the motion of the blood throughout the whole venous system. The works of both these authors are replete with interesting remarks on the circulation in general, and more especially on the flow of blood through the veins. The direct experiments, however, in support of their opinions are comparatively few and inconclusive. Dr. Carson shewed that the lungs are always during life in a state of forced expansion, and estimates the pressure which the lungs of the sheep are capable of sustaining, when in the expanded condition, as equal to a column of seven inches of water. Sir D. Barry observed, in experiments made upon horses, that when one end of a tube is introduced into the jugular vein, and the other extremity rests in a vessel containing water, the water rose during each inspiration some length in the tube, and sank again during expiration, distinctly indicating the diminished pressure existing within the chest at the time of the rise of the water, and proving that the flow of the blood in some parts of the veins may be accelerated during inspiration from the same cause. Poiseuille,‡ by the employment of the instrument for measuring the pressure of the animal fluids, to which allusion has already frequently been made, has confirmed Sir D. Barry's statement, that the diminished pressure within the chest, at the time of inspiration, is such as to affect the flow of

* Annales des Sciences Natur. tom. xxviii. p. 65.

* Inquiry into the Causes of the Motion of the Blood, &c. Liverpool, 1815.

† Experimental Researches on the Influence of Atmospheric Pressure upon the Progression of the Blood in the Veins, &c. Lond. 1826.

‡ Loc. citat.

blood in the jugular vein, and to draw it in some degree towards the heart. In many persons, particularly the young and those of a thin habit of body, the jugular veins in the neck are frequently very distinctly seen to become full during expiration, and to be rapidly emptied and collapsed during inspiration,—a fact which shews clearly enough that the blood passing through this vein enters the chest most easily when that cavity is dilated. The position, however, of the body has a very considerable influence on this rapid evacuation of the jugular veins in such instances. Again, there are several direct experiments upon animals which are much opposed to the views at present under consideration.

Dr. Arnott* has shewn very successfully that such a power as that supposed to aid the venous circulation could have very little effect in promoting the flow of fluids through soft tubes, which collapse as easily as the larger veins do, because not more than an inch of fluid at the most can be drawn through one of them by a syringe, without its sides being brought together so as to close the mouth of the syringe, and this objection is in no way removed by the circumstance that the veins are kept open by the *vis à tergo* of the heart, because even although they should be open, a *force from before*, to adopt the incorrect expression frequently applied to a suction power, if strong enough to make any impression on the flow of the blood, would act, to a certain amount, just in the same way as if no force from behind existed; that is, it would tend to make the sides of the vessel come together, and would thus offer an obstacle to the further progress of the blood.

In repeating some of Barry's experiments, Mr. Ellerby† found that when he introduced a tube into the jugular vein of an ass for two or three inches only, there was no suction exerted through it, but that the fluid in which its further extremity was immersed rose only when the tube was thrust eight or nine inches into the vein so as to reach the chest, in which case, of course, the vein was held open by the rigid tube, and the suction power was enabled to act through it to an extent which does not take place in the natural state of the jugular vein. Messrs. Ellerby and Davies‡ also found that the venous circulation was for a short time not materially impeded by opening the chest or the introduction of tubes into it through the parietes. It must be apparent to every one that the suction power or *vis à fronte* can exert little, if any, force of traction on the blood in the large or superficial veins of the limbs, for on making pressure upon the trunks of one of these, so as to prevent the action of the *vis à tergo*, we find that if the limb is at rest the motion of the blood in the part next the heart is wholly arrested. But if, while we maintain the pressure on the vein at one place we empty the vein for some way towards the heart, close the vein on the side next the heart, and then remove the pressure from the remote situation, the blood is at once impelled through the portion of the vein which had been emptied, by the force of the heart alone. Messrs. Ellerby and Davies have shewn that the same phenomena, or the absence of a *vis à fronte* and evidence of a *vis à tergo*, attend the flow of blood in the largest veins even, which are situated in the immediate neighbourhood of the chest; for after the application of a ligature upon the vena cava inferior, it was found that the part of this vein between the ligature and the chest was not emptied towards the heart, and that when the part of the vena cava in the immediate vicinity of the chest was emptied, and pressure then applied at the entrance of the vena cava into the auricle, the blood rose to fill the emptied portion of the vena cava, although no suction power could in this place operate. It was also found that no fluid rose in the remote extremity of a tube introduced into the femoral vein.* These experiments shew that a suction power, whether produced in the way supposed by Dr. Carson, or in that stated by Sir D. Barry, can have very little effect in promoting the flow of blood in the veins,—a conclusion which is rendered still more certain from some other general considerations, such as the following:

1. The whole of the vessels belonging to the pulmonary circulation are placed within the chest, and consequently the flow of blood in the pulmonary veins must be independent of any suction power connected with respiration.†

2. In the fœtus, as there is no pulmonary respiration, both the pulmonary and systemic venous circulations go on without any assistance from a suction power. And

3. In the portal circulation of the higher animals and in the venous circulation of fishes breathing by gills, as well as of those reptiles in which air is forced into the lungs by a process of deglutition, there can be no aid derived from a suction power.

We have already, in our description of the varieties of form in the circulatory organs of animals, adverted to the intimate relation which very generally subsists between the structure and functions of the organs of circulation and respiration. We shall now mention a few other circumstances connected with the functions of circulation in the adult human body, which seem to depend upon this relation of the motion of the blood to the respiration.

The influence of the mechanical operations of respiration is not confined to the venous circulation, for it has been shewn by direct experiment that the force of the blood in the arteries varies also from the same cause, being greater during expiration than during inspiration. This greater force of the blood in the arteries during expiration, known to Haller, Lamure, and Lorry, was proved by the experiments of Hales, Poiseuille, and Magendie‡ formerly mentioned.

* Elements of Physics, vol. i.

† Lancet, vol. xi. p. 326.

‡ Lancet, vol. xi. 606.

* See also Macfadyen's Remarks, Edin. Med. and Surg. Journal, vol. xxii. p. 271; Carus in Meckel's Archiv. iv. p. 413; and Remarks in the Edin. Journ. of Med. Science, vol. ii. p. 462.

† See the late Prof. Turner's Essay on the Motions and Sounds of the Heart. Med. Chir. Trans. of Edin. vol. iii.

‡ Journ. de Physiol. vol. i.

It is very probably occasioned in part by the assistance which the ventricular systole receives from the collapse of the parietes of the chest at the time that the air is expelled from that cavity, and in part by pressure of the parietes of the chest upon its contents, and through them upon the trunks of the larger arteries. During inspiration the pressure must be, to a certain amount, removed from the larger arteries, and consequently the current of blood through them at that period will be less forcible and less rapid.

The well-known fact that rupture of aneurisms of the large arteries and effusion of blood within the cranium in apoplexy are more liable to occur during straining and other muscular efforts associated with forcible expiration, is a further illustration of the fact that the arterial pressure is greatest at the time of the collapse of the parietes of the chest.

The relation of the force and frequency of the pulse to the activity of the respiration is an interesting subject connected with the facts at present under consideration.* In many persons, in ordinary and tranquil respiration, the force and frequency of the pulse vary perceptibly during inspiration and expiration, and in these persons, when the respiration is more forcible than natural, the pulse indicates very distinctly by its changes the varying states of the chest. During an unusually long and forcible inspiration the beats of the pulse are more rapid and weaker, and during a succeeding complete expiration, or even while the chest is kept expanded, the pulse is more full, strong, and slow. Some individuals have the power of occasioning an intermittent pulse, and some of causing the action of the heart to cease even by forcible exertion of the expiratory muscles. We think it probable that it may have been in this or some similar indirect manner that the action of the heart was arrested in Colonel Townsend's case, described by Dr. Cheyne in his work on the English malady, and very often referred to as a proof of the possession by Colonel Townsend of a voluntary power of influencing directly the heart's action.

There is in general a very constant proportion in the ordinary state of the circulation between the number of the beats of the pulse and the frequency of respiration. The average number of respirations in a healthy person may be considered as from 15 to 20 in a minute, and taking the number of the pulse in the same time at from 72 to 75, this makes one complete respiratory motion for nearly four beats of the heart. The force and frequency of the heart's action and consequent state of the pulse are well known to be considerably influenced by very slight muscular efforts, as well as by changes of position of the body even; but it is not observed that the respiration becomes invariably more or less hurried in a corresponding degree with an increased or diminished frequency of the pulse. In very violent exercise, it is true, and more particularly in rapid motions which give rise to a great and immediate increase of the frequency of the heart's action, the respiration becomes hurried and forcible, or there is panting; but, on the other hand, it does not appear that the gradual changes of the pulse, which are liable to occur from one period of the day to another, are accompanied by corresponding variations in the frequency of respiration; and again, when by a voluntary effort we breathe very hurriedly, as for example, from 80 to 100 times in a minute, the frequency of the pulse is not increased by more than 8 or 10 beats in a minute.*

Some physiologists hold the opinion that the motion of the blood in the capillaries of the lungs and the system is considerably influenced by the chemical changes which the blood undergoes in its passage through the minute pulmonary and systemic vessels. We are not acquainted with any facts or experiments which shew that the systemic capillary circulation is immediately dependent upon the change of the arterial into venous blood: on the contrary, such an opinion is much opposed by the facts that a free circulation of imperfectly arterialized blood takes place in the fœtus before birth, as well as in many children after birth affected with malformations of the heart or greater vessels, and that a completely venous blood circulates through the system in hybernating animals when in the state of deepest torpidity. There are, however, several circumstances which appear to justify the opinion that the motion of blood through the pulmonary capillaries has a more immediate dependence on the change of arterialization.† In all those circumstances which cause imperfect respiration and prevent the accustomed necessary arterialization of the blood, or in approaching asphyxia, it seems to follow from the experiments of Dr. Kay, Alison, and Reid, that there occurs from the very first commencement of the symptoms of impeded respiration, a diminution of the quantity of blood which passes through the pulmonary capillaries. There is thus produced from the first commencement of non-arterialization of the blood an accumulation of venous blood in the pulmonary capillaries and arteries, but it is equally well proved that a certain quantity of venous blood does, as Bichat shewed, gain the left side of the heart and permeate the arterial system. As the symptoms, however, of suffocation or asphyxia become more urgent, the accumulation of blood in the pulmonary artery on the right side of the heart and in the systemic veins gradually increases, until by the time that the involuntary motions of respiration have ceased, there appears to be a complete stagnation in the lungs, although the heart continues to beat a little longer. During the occurrence of these changes the action of the heart also is no doubt gradually becoming weaker, a circumstance which may very probably contribute to the stagnation of the blood in the lungs, but there is good

* See an interesting Essay by Hering in Tiedemann's Zeitschrift, vol. v.

* See an account of the interesting experiments by M. Roulin on the variations of the pulse at different heights. Magendie's Journ. Jan. 1826.

† See Dr. Alison's Remarks, loc. cit.

reason to think that the motion of the blood is first arrested in the pulmonary capillaries.

The state of our knowledge does not, it must be confessed, permit us to offer a satisfactory explanation of the cause of the above-mentioned phenomena. We have already stated reasons against regarding the stagnation of the blood in the lungs in asphyxia as attributable to a loss of the supposed vital power of motion belonging to the blood in the capillary vessels: and we think it quite as just to regard the stagnation as the effect of over-stimulation and constriction of the minute vessels of the lungs by the dark blood, as to attribute it, in the manner some have done, to the deficiency of that stimulation which arterial blood, without any good reason, is presumed by them to give to the small vessels.

2. *Circulation within the cranium.* — The limits of this essay do not permit us to do more than allude very shortly to the nature of the circulation within the cranium,—a subject, in some respects, nearly related to the facts just stated, and of great importance from the general dependence of the state of the cerebral functions upon the quantity and force of blood which flows through the brain.

The bloodvessels within the cranium are differently situated from those in other parts of the body in this respect, that they are removed from the influence of atmospheric pressure. In consequence of the unyielding nature of the skull, and its being closed on all sides, excepting at the places where the nerves and bloodvessels pass through the bones, the cavity of the skull must necessarily be equally full at all times; and the spinal canal is in the same predicament.

The whole quantity of fluid or solid matter, then, within the cavity of the cranium and spinal canal must be always the same; or, during the circulation just as much blood must issue as enters it, and it is physically impossible to increase or diminish the whole quantity contained in the brain by increased pressure, by opening of an artery or vein or any other means. It was shewn by various well devised experiments performed by the late Dr. Kellie,* that in animals bled to death, while the rest of the body was exsangueous, the brain retained its usual appearance so long as the vault of the cranium was entire, but that a perforation of the skull, such as to allow the atmospheric pressure to act upon the brain and bloodvessels of the head, caused the evacuation of blood from the head as from other parts of the body.

While the whole bulk of the contents of the cranium, however, must necessarily remain the same, yet the relative quantity of arterial and venous blood may vary within a short space of time, the pressure exerted by the blood in the vessels may be greater or less according to circumstances; and there may occur within the skull local determinations or partial distributions of the blood. When from rupture of a bloodvessel, inflammation, suppuration, or other causes, blood, serum, or pus are effused into the cavity of the cranium, the circulating blood must be diminished in quantity; when there is any obstruction to the return of the blood by the jugular veins, the pressure of the blood entering by the carotid artery is proportionally greater; and when the arteries which supply blood to the brain are obstructed, or the heart's action is less forcible than usual, the pressure on the brain must be diminished in a corresponding degree.

In the natural state of the circulation the pressure exerted by the blood circulating through the cranium is subject to regular alternations of increase and decrease from the effect of the heart's action and the motions of respiration. When the brain of man or of animals is exposed by the removal of a part of the skull, it is seen to be slightly raised at the exposed part at each arterial pulsation, and more perceptibly during each expiration. The brain falls again during each succeeding inspiration, but does not sink below the level of the skull. These motions may also be perceived at the fontanelles of the infant's head, where the bony parietes of the skull are deficient. In the closed state of the skull, for the reasons previously mentioned, it is obvious that there can be no motions similar to those observed in the brain when exposed, but nevertheless the brain must be more forcibly pressed upon by the blood at these times than at others. Haller, who had observed these motions, conceived the depression during inspiration to be caused simply by the ease with which the blood enters the chest at that time, and attributed the swelling of the brain during expiration to the obstacle then offered to the descent of the blood through the jugular veins. It seems, however, probable that the greater fulness of the arteries during expiration may also contribute to raise the brain at the time when the collapse of the walls of the chest occurs: for Magendie observed, that when a ligature was put upon the jugular vein, the blood which issued from this vein by an aperture above the ligature, flowed with greater force during expiration, shewing that increased arterial pressure during expiration was continued through the capillaries into the veins. Sign. Ravina, who made a very extensive series of experiments upon these motions, found that when the brain has been depressed during inspiration, it again swells, although no expiration succeeds, but that when raised during expiration, it does not again sink, if inspiration does not follow.

3. *Influence of varieties in the distribution of arteries and veins upon the circulation.*—As connected with some of the above-mentioned facts, and exerting a considerable influence in modifying the circulation of the blood in particular states of the animal economy, we may here mention a few of the more remarkable varieties in the distribution of the arteries and veins, together with the uses they have been supposed to serve in different animals. The varieties of form in the larger arteries may be considered under two heads; *a*, simple tortuosity; and *b*, sudden division into many small branches.

* Edin. Med. Chirurg. Trans. vol. i.

a. One of the best examples of the first of these varieties, which are by no means uncommon in animals, occurs in the spermatic arteries of the bull. Two reasons have been assigned for the existence of this, viz. 1, to allow, by the greater length of the vessel, for the stretching of parts, as in the arteries of the lips; and 2, to diminish the velocity of the blood passing through the tortuous vessel, from the longer course and greater incurvation.* Increased friction, which must be the consequence of greater length of the artery, will diminish the velocity of the blood through the whole vessel, and besides this, a given particle of blood passing through a tortuous vessel will arrive later at its destination, in consequence of the longer course it has to run through; but if we regard the fluid in the arteries as every where subjected to pressure, it is very doubtful that the increased curvature can be the source of any considerable retardation by diminishing the force communicated by the impulses of the heart.†

b. The sudden division of an artery into many small branches may take place with or without tortuosity or a plexiform arrangement; the primitive vessel disappearing or persisting, but in most cases when present, diminished in size. The most remarkable examples of this peculiarity of the arterial system are the following. 1. The intercostal and lumbar arteries of the Cetacea in the posterior part of the chest, and in the vertebral canal and the caudal artery of the same animals, which are tortuous and plexiform. 2. The brachial artery of the Porpoise, which divides at once into more than forty plexiform branches. The primitive trunks disappear, and five or more vessels emerge from the distal end of the plexus. The uterine and vesical arteries of the same animal are much divided, but not plexiform.‡ 3. The subdivided brachial and crural arteries of the Bradypus tridactylus, Lemur tardigradus, L. gracilis and L. tarsius; and the same arteries, as well as the caudal arteries of the Myrmecophaga didactyla and M. tetradactyla. 4. The arteries of the legs of the Swan, Goose, and Turkey divide into several long branches, which anastomose with one another.§ 5. The rete mirabile of Galen on the internal carotid of many quadrupeds, and the rete mirabile on the common carotid of the Frog. 6. The rete mirabile of Hovius on the ophthalmic artery of some animals, the Seal for instance. 7. The mesenteric arteries of the Sow at their commencement. 8. The subcutaneous arteries of the Hedgehog.

The uses of these very various forms of arteries it must be confessed is very little known. Some of them may, like other peculiarities in animal structure, and more especially those belonging to the vascular system, be remains of the fœtal condition of the arteries in which they exist.* The most common opinion entertained as to their effect on the circulation is that they retard the velocity of the blood, and render its flow more uniform, thus preventing the parts supplied by them from being affected by sudden changes.† Other secondary consequences of the diminished velocity occasioned by these peculiar structures have been imagined, as for example, 1, diminished rapidity and greater durability of muscular contraction, as in the Sloths; ‡ 2, security against obstruction of the circulation from pressure, as in climbing animals which cling long and forcibly to branches of trees; § 3, or these plexuses have been regarded as intended to increase the capacity of the arterial system, and to serve as reservoirs for blood, as may be the case in the Cetacea.‖ In some of the above-mentioned animals the tortuosity or multiplied divisions of the arteries are accompanied by a similar condition of the veins, as in the Porpoise.

The most remarkable variety in the form of the venous system, and the one to which a use may be most easily assigned, is the large dilatation of the vena cava inferior in the neighbourhood of the liver, which occurs in those animals which from their mode of life are in the habit of remaining long under water, such as the Seal, Otter, and Diving Birds. The purpose of the venous sinuses in these situations is manifestly to allow of the accumulation of venous blood in the vena cava without an unusual distension of the right side of the heart and bloodvessels leading into it and from it, which is the effect of long submersion or impeded respiration in animals unprovided with this peculiarity of structure. The venous and arterial plexuses of the Cetacea very probably serve the same purpose. The muscularity of these sinuses alleged by some must have the effect of emptying them more easily than would be accomplished by the *vis à tergo*.

4. *Influence of the nervous system upon the circulation.*—It is a very general opinion among physiologists that a considerable influence is exerted by various parts of the nervous system upon the function of circulation as a whole, and through it upon the different processes of the economy concerned with nutrition, as digestion, secretion, growth, animal heat, &c. There is some difficulty, however, in ascertaining the exact relation which subsists between particular parts of the nervous and circulatory systems. It is manifest that in many instances the circulation in the bloodvessels is modified by a nervous influence which operates on the heart alone, while in others it is affected by an alteration of the vital powers of the bloodvessels themselves. We refer the reader to the articles CONTRACTILITY and HEART for an account of the modifications to which the circulation is liable from the operation of nervous influence on

* J. Hunter.

† Müller's Physiol. vol. i. p. 198.

‡ See the accounts of these varieties by J. Hunter in the Phil. Trans. Sharpey, Meeting of British Scient. Assoc. in Edin. Sept. 1834. Breschet, Annal. des Scien. Natur. 1834. Baer, Nov. Act. Nat. cur. 1835.

§ Cuvier, Leçons d'Anat. Comp. vol. iv.

* Baer, loc. cit.

† Barclay on the Arteries, p. 36.

‡ Carlisle, Phil. Trans. 1800. Roget, Bridgewater Treatise.

§ Vrolik.

‖ J. Hunter, loc. cit.

the heart alone. We shall only remark in this place that although the heart may be excited to contraction by the direct stimulation of its muscular substance, and although the effect upon the heart's action of bodily exertion, of emotions of the mind, and of severe injuries of the brain and spinal marrow, all of which can be supposed to act upon the heart through the nerves only, are undoubted; yet it is well ascertained that the heart cannot in general be excited to contraction by the direct stimulation of its nerves, and that its action may be regarded as automatic to a certain degree, and little dependent upon the immediate transmission to it of any nervous influence from the cerebro-spinal or ganglionic nervous systems, since the rythmic contraction of the heart continues to go on for a time in some animals after the division of its nerves, and in others even after its complete separation from the body. It has also been frequently found that after the complete destruction of the brain and spinal marrow of an animal the circulation of the blood can be maintained for some time by means of artificial respiration,—an experiment which proves that the motion of the blood in the vessels is not immediately dependent upon nervous influence.*

Many circumstances, however, seem to shew that the state of the vessels, and in consequence of this the velocity and force of the blood, are susceptible of very considerable modification from local affections of the nerves belonging to the part in which they may have been observed to occur, or from general alterations of the nervous powers of the system. It is probable that nervous influence operates much more powerfully in modifying the circulation through the small than through the large vessels, indeed we know of no direct satisfactory experiments which demonstrate the effect of nervous influence upon the larger arteries exclusively.

The experiments which seem to prove most satisfactorily the influence of the nervous system on the circulation in the small vessels are those performed on cold-blooded animals by Legallois,† W. Philip,‡ Flourens, and particularly those of Marshall Hall,§ the general result of which may be stated as the following: that after the destruction, whether sudden or gradual, of the brain or spinal marrow, the flow of blood in the remote parts becomes more languid and is gradually more and more circumscribed, while the action of the heart continues, and its power seems not to be diminished in a proportional degree. But in such experiments as those just mentioned, performed in general in cold-blooded animals, it must be at all times exceedingly difficult to find an accurate mode of measuring the force of the heart, and consequently they cannot be regarded as affording sufficient evidence that there did not occur along with the languid state of the circulation a certain diminution in the heart's power. They do not at least entitle us to conclude that the decreased velocity and stagnation of the blood in the remote parts is caused mainly by the loss of the vital powers of the capillary vessels, for these changes of the circulation may in a great measure be the effect of other causes, as the loss of power of the heart, and that more permanent alteration of the textures which very probably accompany the severe injury done to the body. On the other hand it may be remarked that the coldness and impaired nourishment common in palsied limbs, the known increase or diminution of the various secretions from mental emotions, and direct or sympathetic affections of the nerves belonging to the glands or other secreting organs, the phenomena of blushing, erection, inflammation, and the like are all very direct and satisfactory proofs that the small vessels and the capillary circulation may be influenced by affections of the nerves. As a further confirmation of this may be mentioned, 1, the inflammation and other consequences of the division of the fifth pair of nerves which occur in the eye; 2, the statement of some, as Treviranus, that the division of the nerves of the leg of a frog impedes the circulation: 3, the assertion by others, as Baumgärtner, that after the division of the nerves or the destruction of the spinal marrow, the peculiar oscillations which he, along with Doellinger and Kaltenbrunner, has observed to precede the formation of new blood-vessels do not occur; and 4, the observations of Nasse, which are stated to shew that the reunion of wounds is retarded or put a stop to by the division of the nerves belonging to the wounded part. Krimer,* whose experiments on this subject are numerous and remarkable, states that the circulation was always much impaired by the abstraction of nervous influence from the division or ligature of the nerves; that the jet from the femoral artery of a quadruped was much less strong after the division of the crural nerve; that the capillary circulation of the frog's web ceased soon after the nerves were cut or tied; that the arterial blood passed through the systemic capillaries without undergoing its proper change into venous; and that salt did not produce the accustomed effect of dilating the capillaries when the nerves of the part were injured, but that these effects were induced when galvanic irritation was applied to the divided nerve.

In reference to these experiments it may be remarked that most of them are at variance with experiments of a similar nature performed by others, more especially those of Haller, Spallanzani, Whytt, Fontana, Legallois, W. Philip, Flourens, and M. Hall, none of whom remarked so immediate and complete a stoppage of the circulation from removal of the nervous influence. Again, in palsied limbs the circulation is frequently little or not at all disturbed,

* We refer here to the experiments of Haller, Whytt, Fontana, Spallanzani, Legallois, W. Philip, Cli t, Flourens, and Müller; Humboldt, Fowler, Brachet, Treviranus, Weinhold, &c.

† Expér. sur le Principe de la Vie.

‡ Exper. Inquiry into the Laws of the Vital Functions.

§ Loc. citat. p. 99.

* Physiologische Untersuchungen. Leipzig, 1820.

and sometimes the secretions, natural growth of parts, and reunion of wounds have been found to be little impaired by injuries of the nerves. We may therefore form the conclusion, that although the circulation in the small vessels is obviously liable to be modified by the state of the nerves in their neighbourhood, or perhaps by affections of the nervous system in general, there is no reason to consider the capillary circulation as more immediately dependent on nervous influence than the action of the heart.

BIBLIOGRAPHY.—We have deemed it advisable to reserve our historical sketch of the discovery of the circulation and the knowledge of that important portion of physiology to this part of the article, thereby consulting brevity in uniting it with the literature of the subject.

The Chinese have been conceived to have entertained correct notions of the circulation before they had any intercourse with Europe,—a supposition, the erroneousness of which is sufficiently demonstrated by their description of the commencement of the circulation of the radical humours and vital heat at three o'clock in the morning, their passage through the lungs in the course of the day, and termination in the liver at the end of twenty-four hours, as well as by the different manipulations practised by them in the operation of venesection.

In the time of Hippocrates and Aristotle, although the principal bloodvessels were described—apparently from dissection of animals,—the course of the blood appears to have been wholly unknown.

Towards the end of the second century Galen describes accurately the distribution of many of the bloodvessels in the lower animals. He appears also to have known the anastomoses of the arteries and veins, and the structure and uses of the foramen ovale in the fœtus, but his works afford no evidence of his having known the course of the blood in either the pulmonic or the systemic circulations. He described the arteries as arising from the heart, the veins from the liver; and some of those passages of his works in which it is alleged that the circulation of the blood is pointed out, are either inconsistent with one another, or are believed to have been introduced at a later time than Galen's. Galen believed that the blood passed through the septum of the ventricles; he knew that the arteries contained blood, but he believed its motion to be of an oscillatory kind. (De usu partium, l. iv., vi., & vii., and his treatise on the question—*an sanguis in arteriis naturâ continetur?*)

The authors of a more recent date, in whose works it has been supposed that the circulation was described, are Servetus, Columbus, and Cæsalpinus. After the revival of letters, the great anatomist Vesalius of Brussels, in 1542, had examined more minutely than his predecessors the connections of the arteries and veins: he mentions the valves of the veins, the difference between the veins and arteries, and describes the valves of the heart. He seems to have known that the blood was propelled into the arteries by the heart, and demonstrated by a more direct experiment than Galen's, that the arterial pulse depends on the systole of the heart. (De corporis humani fabricâ, fol.; and Opera Omnia, curâ Boerhaave.)

Servetus, the victim of religious persecution in 1553, is one of those in whose writings we find the first dawn of part of the discovery of Harvey, for he very distinctly at one place refers to the pulmonary circulation. The vital spirit (blood) passes by the arteries into the veins by their anastomoses. The blood cannot pass from the right into the left auricle on account of the closed nature of the septum auricularum; in the adult it must go through the lungs, where it is charged with the vital spirit obtained from the atmospheric air, and then returns to the heart. He further held that the pulmonary artery and vein from their large size must have some other use than the nourishment of the lungs merely. De Trinitatis Erroribus. Basil, 1531.

Columbus, Professor at Padua and Rome, six years after the publication of the work of Servetus, published the discovery of the lesser circulation as his own. He describes it more clearly than Servetus does, and held that the blood returning from the lungs is not mixed with vital spirit, but is quite pure. Libri xv. De re anatom. Venetiis, 1559.

Cæsalpinus of Arezzo, Professor at Pisa, gave, in 1583, a more detailed description of the pulmonary circulation than any of those who preceded him, and in two parts of his work expresses himself in such a manner as to shew that he had some idea of the systemic and double circulation. Other passages in his works are, however, quite inconsistent with a correct knowledge of the course of the blood, and, although we find this course more nearly indicated in the writings of Cæsalpinus than in any others before the time of Harvey, he does not seem to have added much, if any thing, to the knowledge possessed by those who preceded him, but rather to have applied, and without acknowledgement, the observations of Vesalius, Fallopius, Servetus, and Columbus, to the explanation of the circulation.

The fœtal circulation seems to have been examined with great attention by the anatomists of the sixteenth century. Galen had already been acquainted with the foramen ovale, and also knew, though less perfectly, the ductus arteriosus. Fallopius described the ductus arteriosus exactly, so also did Vesalius and Aranzii; and after this Botallus appropriated to himself the discovery of both the foramen ovale and ductus arteriosus. Vesalius discovered the ductus venosus which was figured by Fabricius and Eustachius. Fabricius ab Aquapendente made the discovery of the valves of the veins and published it in 1603: it is surprising that knowing their structure so perfectly as he did, he should have continued ignorant of their uses, and strictly attached to the older erroneous opinions regarding the circulation.

Dr. William Harvey was born at Folkstone in Kent, and studied under Fabricius at Padua from 1598 to 1602. Learning from his master the structure of the valves of the veins, he engaged in experimental researches after returning to England, with the view of determining their uses, and in 1619, according to his own statement, taught publicly for the first time the doctrine of the double circulation of the blood, which he had demonstrated by his investigations. He did not publish any history of this discovery until after the lapse of nine years, during which he had carefully examined his doctrines and experiments. This appeared in the Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus, first published at Frankfort in 1628.

Among the contemporaries of Harvey who supported his views, the following authors are remarkable.

Werner Rolfink, Professor at Jena, one of the first to adopt the new view, published two years after the publication of Harvey's work.

Des Cartes upon two occasions supported Harvey's views, viz. in 1637 and 1643, having been answered by Plempius.

John Walæus, Professor at Leyden, may be regarded as one of the most original of those who adopted and defended the new view. In 1640 he published two letters, addressed to Thomas Bartholin.

Herman Conring of Hermstadt.

James de Back, Amsterdam, 1649.

John Trullius, 1651, Rome.

George Ent of London.

Riolan was the only one of his opponents whose objections Harvey thought it worth while to answer. This he did in two additional Exercitationes, which are published in the Leyden edition of his works, 1737. In a journey which Harvey made to Germany, he endeavoured to demonstrate his views to Hoffman, but without success. In 1652 Plempius acceded the merit of discovery to Harvey, and adopted his views of the circulation. Harvey died at the advanced age of 79, in the year 1657, after having had the satisfaction of seeing his views generally adopted by the best-informed anatomists and physiologists, and after having enjoyed the glory due to so great and valuable a discovery.—The best edition of Harvey's treatise on the Circulation is that to be found in the edition of his works published by the London College of Physicians, in 4to.

About this time the experiment of transfusion, proposed some time previously, seems to have been first successfully performed by Dr. Timothy Clarke, Boyle, and Henshaw, as also by the celebrated Lower at Oxford, in 1660, affording additional proof of the correctness of the views of Harvey.

Although the double course of the blood through the pulmonic and systemic circulations was fully demonstrated by these investigations, the direct passage of the blood from the smaller arteries into the veins had not yet been observed.

After the introduction of the use of the microscope, this additional proof was supplied by Malpighi, who discovered the capillary circulation in the vessels on the lungs and mesentery of the frog in 1661 (Epistola de pulmonibus).

Malpighi observed the passage of the globules of the blood through the minute vessels, and thus satisfactorily proved that there is an actual transmission of the circulating blood from the arteries to the veins in both the systemic and pulmonary circulations.

Leuwenhoeck, in 1673, repeated the observations of Malpighi on the capillary circulation, and extended them to different animals, at the same time adding to their value by the discovery of the nature of the colouring particles or globules of the blood (Philos. Trans. No. 102). The structure of the minute vessels in different parts of the human body was shortly after this very fully shewn by the fine injections of Ruysch, and the analogy between the structure of the minute vessels in Man and the lower animals thus fully established.

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When the course of the blood in the double circulation had been fully established by the abovementioned observers, and the views of Harvey were universally adopted, the labours of anatomists and physiologists were directed to the more minute and detailed investigation of the different processes of the circulatory function.

The works of Lower, Lieutaud, and Senac on the heart, and of Hales, Haller, and Spallanzani on the motion of the blood, were among the more important of those which appeared during the last century which contributed to advance the knowledge of our subject.

The second volume of Dr. Stephen Hales's Statical Essays, 1733, contains the history of the numerous experiments made by that ingenious philosopher, with a view to investigate the hydraulic phenomena of the circulation and the first accurate measurements and calculations of the force of the current of blood in the arteries and veins, its velocity, the power of the heart, &c.

The works of Haller on the circulation consist,

1st, of the greater part of the first and second volumes of the Elementa, containing a complete history of the structure and functions of the organs of circulation;

2d, Deux mémoires sur le mouvement du sang, &c. Lausanne, 1756: the first memoir containing the results, the second a detailed account of the experiments.

These Memoirs are also published in the Opera Minora; also, in English, Lond. 1757.

3d, Deux mém. sur la formation du cœur dans le poulet, Laus. 1758.

The work of Spallanzani, entitled Experiments upon the Circulation of the Blood, translated by Tourdes into French, Paris, An viii., and by R. Hall, M.D. into English, Lond. 1801, contains a great body of most accurate observations and experiments.

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(*Allen Thomson.*)

CIRRHOPODA; *Cirripedia; Cirripeds;* (κιῤῥὸς and ποῦς, *cirrus* and *pes*, from the curl-like form which the coiled feet or arms present. Fr. *Cirripèdes.* Ger. *Rankenfuesser.*) A class of invertebrate animals, composed chiefly of the barnacles and acorn-shells. They are related in some points of structure with the annulated or diploneurose animals, particularly with Crustacea; in other points they resemble Acephala (Conchifera). All are marine and fixed. The soft parts are, for the most part, encased in a multivalve shell. The body is somewhat conical in form, tumid, and bent inwards at the oral extremity, tapering towards the opposite extremity, where it terminates in a long pointed tube. Placed along the abdominal surface, there are two rows of fleshy lobes, (six on either side,) each having two long horny processes, jointed and ciliated. In some species, these constitute the chief bulk of the whole animal. The head is indistinctly defined, and has neither eyes nor tentacles; mouth with lips, and three pairs of horny jaws; anus at the base of the tubular process. Respiration is effected by branchiæ, which, in some species, are filamentary, in others foliated. Mantle membranous, sacculated, provided with a slit-like opening for the passage of the arms, &c. Between each two pairs of arms, the abdominal surface is marked by six slight depressions, which may be regarded as an approach towards complete articulation.

The animals thus characterized have had different places assigned to them in the various systematic arrangements of modern zoologists. Cuvier formed of them the sixth and last class of his Mollusca. Lamarck was at one period inclined to place them amongst the Crustacea, but latterly he constituted for them a distinct class, and placed it between Annelida and Conchifera; still, however, regarding them as more closely allied to Crustacea than to any other class; "for," as he remarked, "they have the nervous system of Crustacea, they have jaws analogous to those of the animals of that class, and their tentacle-like arms resemble the antennæ of the lobsters."* Bur-

* An. sans Vertèbres, v. 377.

meister also places them amongst the Crustacea. De Blainville arranges them, under the name of Nematopoda, as a class of his subtype of the Mollusca — Mollusc-articulata; the other class of the subtype being formed of the Chitons (Polyplakiphora). He regards them as Crustaceous Mollusca, but admits that they seem to form a transition group uniting the Crustacea with the Annelida. M. St. Ange,* however, would rather class them with the Annelida, on account of the closer resemblance which the arrangement of their nervous system bears to that of these animals. Professor Wagner does not doubt that they are really articulated animals, but he would rather place them in a distinct class between the Mollusca and Articulata. Setting aside their nervous system, M. Serres sees, in the other parts of their structure, points enough to induce him to arrange them with the Mollusca. The same views are entertained by Wiegmann, Goldfuss, and others. Dr. Leach regarded them as truly annulose animals. Dr. Grant (who calls them " entomoid animals enclosed in shells") places them amongst the Articulata, or diploneurose animals, between Rotifera and Annelida, making of them a distinct class, but admitting their great resemblance in many points to the entomostracous Crustacea. Mr. J. V. Thompson (whose admirable researches on the development of the Cirripeds have thrown a new interest around them) holds it as proved by his observations that the Cirripeds do not constitute a *distinct class;* but that they are naturally and closely connected, on the one hand, with the Decapod Crustacea, through the Balanids, and, on the other, with the Entomostraca, through the Lepads; further, that they have no relation with the Testacea.

All the known Cirripeds may be naturally grouped into two families, one pedunculated, the other sessile. The former includes all the barnacles, properly so called; the latter, the acorn-shells. The barnacle family have had the name of Campylosomata applied to them by Dr. Leach, who calls the other family Acamtosomata: but we shall use De Blainville's synonyms of Lepadicea and Balanidea. The following are the names of the genera generally used at present: —

I. Lepadicea.

1. Otion. 2. Cineras. 3. Anatifa. 4. Pollicipes. 5. Scalpellum.

II. Balanidea.

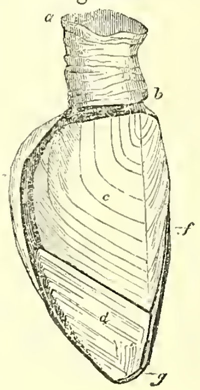
1. Balanus. 2. Ochthosia. 3. Conia. 4. Creusia. 5 Clisia. 6. Pyrgoma. 7. Acasta. 8. Coronula. 9. Tubicinella. 10. Chelonobia.

External coverings and organs of support.— There are three principal modifications of the tegumentary organs in this class. The first is that seen in Anatifa, in which it assumes the form of calcareous plates, united by horny ligament, and attached to a cartilaginous peduncle. The second form is that common to all the Balanids—a calcareous cone, composed of separable pieces, sessile, and provided with an opercule of shelly plates. The third form is a general cartilaginous covering, sometimes strengthened by small calcareous plates.

* Mém. sur les Cirripèdes. Paris, 1835.

The shells of the Cirripeds are similar in general appearance to those of many Acephalous Mollusca. They are most fully developed in Anatifa, which has five separate plates, four placed laterally in pairs, and one median. One pair is considerably larger than the other (*c*, *fig.* 332); it covers all the anterior part of the animal, and the greater part of the internal organs. The bases of these shells are attached to the cartilaginous peduncle; the lower halves of their anterior edges form part of the margin of the slit-like opening through which the arms are protruded (*f*, *g*, *fig.* 332). The inferior pair of shells (*d*) are of a triangular form; the smallest side completes the margin of the brachial orifice; another side is united by ligament to the upper valve; the third is connected with its fellow by the common intervalvular ligament.

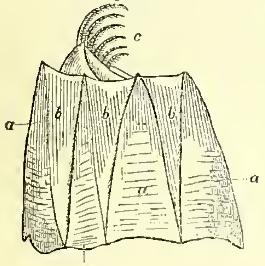
Fig. 332.



The median piece (*e*) covers the dorsal aspect of the animal. It has an elongated lanceolate shape, curved and grooved internally. Its upper point only is inserted into the peduncle. Its margins are imbedded in the intervalvular ligament. This piece may be compared to the unpaired valve of the shell of *Pholas:* it occupies nearly the same situation. The surface of these shells is generally denuded of epidermis, excepting just around their margins. All three are strongly and regularly marked with lines of growth, from which it is seen that the two pairs of lateral valves increase in size, chiefly, by additions to their margins, which look towards one another; so that the parts first formed are, in the adult animal, removed to the greatest possible distance from one another. In the upper valve, the umbo or centre of growth is situated in the anterior-superior angle, close to the termination of the peduncle; in the lower, it is situated in the anterior-inferior angle; and in the dorsal valve, in the point next to the peduncle. All the shells are thin, diaphanous, of nearly the same thickness throughout, yet much less fragile than shells of Acephalous Mollusca which otherwise resemble them. It has been remarked by Burmeister that the shells of Cirripeds resemble those of crustaceous animals more than those of Molluscs: to us it appears that they have a greater degree of density, and a more compact crystalline structure than are commonly met with in Crabs; and that their well-marked lines of growth give them a closer resemblance to shells of acephalous mollusca. In some genera, as Pollicipes, in addition to the five valves just described, there are other eight smaller calcareous plates arranged around the junction of the peduncle with the shells.

The shells of the Balanids present several striking peculiarities of structure, and, in their mode of growth, offer to the physiologist an interesting subject for investigation. They form truncated cones, the bases of which, without the intervention of peduncles, are fixed to rocks, floating wood, integuments of marine animals, &c. These cones are composed of several pieces, closely cemented together so as to admit of no motion between them, excepting during the process of enlargement of the shell. In the common acorn-shells (*fig.* 333), which cover our littoral rocks and the bottoms of ships, there are seven of these pieces, six forming the walls, and one discoid, forming the base. The outer surface of the parietal valves is marked by the lines of growth in such a manner as to give it the appearance of being composed of twelve pieces. These may be termed *compartments*. They are all conical. Six of them have their bases applied to the common base of the shell, and the other six are inserted between these, with their apices towards the common base. The first six we shall refer to under the name of the *first series* of compartments (*a*, *a*, *fig.* 333); the other six constitute the *second series* (*b*, *b*, *fig.* 333). The opening in the summit of the cone is closed by an opercule composed of four shelly pieces so arranged as to leave a longitudinal fissure between them, through which the arms are protruded (*c*, *fig.* 333). The two series of compartments differ much from one another in their external aspect, owing to the differences in the directions and appearances of the lines of growth. The second series have a smoother surface, and are marked with very delicate lines, both longitudinal and transverse; they are also less prominent than the first series. The lines on the first series are chiefly transverse, and correspond with the outline of the base. On the internal surface of the walls there are six deep grooves, in the bottoms of which are seen the openings into certain chambers, constituting a sort of diploë of the valves, hereafter to be described. These grooves run from the summit to the base of the shell, and are the internal edges of the sutures of the six parietal valves. Around the internal margin of the common base there is a series of holes opening into certain tubes that terminate on the outer margin of the shell. When all the valves are separated at the sutures, it is found that each of four of the six compartments of the first series, as they appear externally, has attached to its dorsal margin one of the second series, and that the union between these two is exceedingly intimate, in fact that they form one piece, notwithstanding their apparent division externally. Two of the second series of compartments are attached to the anterior valve, while the dorsal valve has none. The anteal margins of the lateral valves and both margins of the dorsal valve are marked by transverse depressions corresponding to the numerous partitions of the chambered compartments which are fitted into them; and, externally, each has a projecting margin. To the upper part of the inner surface of each valve there is attached a laminated process, forming part of a circle of calcareous plates which gives support to some parts of the mantle.

Fig. 333.



The internal structure of these shells presents some peculiar features. They all contain numerous tubes and cavities, regularly arranged, and forming a sort of diploë. The suture-holes mentioned above open each into a separate canal, chamber, or tube. Those which occur in rows on the walls of the cone lead to small chambers within the second series of compartments, running parallel with the general base, and separated from one another by delicately-formed partitions, each of which is deeply grooved on both sides. The partitions are placed at equal distances, and their grooves are most regularly formed. The whole presents one of the most beautiful and delicate pieces of structure with which we are acquainted in the whole range of extravascular skeletons. These are from thirteen to fifteen on either side of each partition. *Fig.* 334 represents a perpendicular section of a few of these grooved partitions considerably magnified. *Fig.* 335 represents a horizontal section of one of the six valves. The holes forming the sutures are at *a*. The grooved floor of one of the chambers of the piece is between *a*, *d*, and *c*. *d*, *c* is the outer wall of the compartment of the second series. *a*, *b* is a section of that part of the valve which appears outside as a compartment of the first series. Its diploë is composed of tubes, running from the apex to the base, gradually enlarging below. Horizontal sections of those tubes shew them to be of an ovate form, tapering inwardly (*fig.* 336). They are placed nearer the outer wall than the inner. The spaces intervening between the tapering sides of the tubes are marked with lines of growth, shewing a gradual filling up of the tubes from within outwards; and also the previous existence of furrows or grooves on the surfaces of the partitions between the tubes. These

Fig. 334.

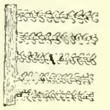


Fig. 335.

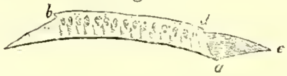


Fig. 336.

grooves are very strongly marked in some species, as in *Balanus Spinosus* (*fig.* 337), where the tubes are large, and the walls comparatively thin. In all they run in straight diverging lines from the apices of the compartments to their bases. There they open close to the margin of the general base. In most species, however, their orifices are, in part, filled up by an extension of the base (*a*, *fig.* 338). In some small species, the tubes of which are wider than those of larger ones, there is hardly any opening discoverable externally, or at most a very narrow fissure just around the margin. Very near their terminations on the margin, these tubes of the diploë are joined by the very short canals which proceed from the inner circumference of the base (*b*, *fig.* 338), and it is at their junction that the grooves in the walls of the partitions are most obvious. These two sets of tubes communicate freely all around the margin with the diploë of the base. All the Balanids—with the exception of the Coronules—have calcareous bases. The structure of the base differs from that of the walls in being composed internally of large oval cells irregularly arranged. These cells seem to communicate freely with one another and with the tubes of the valves. The Coronules have no base: their soft parts are in immediate contact with the integuments of the living animals in which they are generally imbedded.

Fig. 337.

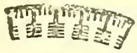
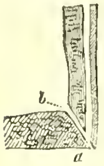


Fig. 338.



The form and arrangement of the opercule vary. There are generally four triangular valves, two larger than the others, all deeply grooved on their upper surfaces by the lines of growth. These valves cover more or less completely the soft parts beneath, to which they are attached, so as to be very moveable one upon the other, and to admit of the passage of the feet through the slit that exists between the two pairs. In some of the coronules, the greater part of the opercule is soft. *Coronula diadema* has two small shelly plates in its opercule.

Keeping in view the complex but beautiful structure just described, it is not difficult to determine how the whole shell increases in size. It is obvious that the parietal compartments of the first series are enlarged by additions to their basilar edges and internal surface, and that thus the whole cone is lengthened, and consequently widened at its base; but, in all the species, it is also widened above; and, as the summits of the first series of compartments are, evidently, not at all, or, at most, very slightly, abraded by the friction of the opercule, it is certain that the apices of these compartments—originally very closely approximated—must be moved outwards and separated from one another by the gradual increase in breadth of the intervening wedge-like compartments of the second series. This process implies the insertion of soft parts endowed with vascular action between the valves so as to admit of lateral additions being made to the second set of compartments. There can be no question that these soft parts (foliated processes of the mantle) pass into the sutures along their whole length, and deposit the shelly matter on the edges of the partitions forming the chambered structure of the second series of compartments; each valve, with the exception of the dorsal one, is thus added to in breadth; and as the distance between the original valves is enlarged, and the whole shell lengthened, new chambers are formed below. Of course, as the cone is lengthened, its base is widened; and this is effected by the excretion of shelly matter from such parts of the mantle as can easily pass through the numerous holes placed around the inner circumference of the base. The valves of the opercule are imbedded in the margins of the mantle between the epidermis and true skin, and are increased by marginal additions in the same way as the shells of molluscs.

The mode of growth of these shells engaged the attention of Cuvier, who concluded that an addition to the sides of the valves could take place only in an early age; for it appeared to him that they are, in a more advanced stage, so firmly cemented together as not to admit of separation. In large species, however, we find that the valves are easily separated at the sutures, and that the calcareous matter along the sides of the sutures is loosely aggregated; so that, to us, there seems to be no improbability in the supposition that in the living animal the prolongations of the mantle pass between the terminations of the minute tubular processes of the second series of compartments, and the corresponding depressions in the edges of the first series already noticed. There is no indication, we think, of each of the valves being "detached from its neighbour *only* at certain times that it may receive additional calcareous matter along its sides," as Brugières and Cuvier imagined. The process of growth seems to be carried on in uniform progression until adult age. So puzzling did the problem of the mode of growth in these shells appear to Dufresne, that he concluded that, like crabs, the Balanid casts its old shell, and forms a new one, as it increases in size.* Cuvier remarked that, "while the mode of growth of the shells of the Mollusca resembles that of simple teeth, the organization and increase of the shells of balanids may be compared to that of certain compound teeth, particularly those of diodons and tetrodons."

Tubicinella, a parasite of the Whale, differs much from the other balanids in the formation of its shell. The widest part of its six-valved cone is superior; the whole surface is strongly ribbed, and marked with transverse lines of growth; and it appears that the additions to the cone are made on the upper margin; this margin is surrounded internally by a thick and fleshy production of the mantle, which is never altogether covered by the opercule. The base

* Ann. du Mus. i. 467.

is open, and of little less diameter than the upper part, which led Dufresne to conclude that the animal does not form a shell until it be considerably advanced in growth. This seems to be very probable, as the base is imbedded deeply in the integument of the Whale, and descends lower the more it increases in size, so as to leave only the summit of the shell visible. The imbedded portion is generally deeply coloured by the tegumentary pigment of the Whale. In coronula, which also inhabits the backs of Whales, but has the same general structure of shell as the majority of Balanids, the valves are deeply partitioned, and provided with toothed processes, fitted to fix the animal in its site.

The only other calcareous coverings that remain to be noticed are the rudimentary valves in *Otion* and *Cineras*, animals that bear a general resemblance in form to *Anatifa*, but which are covered chiefly by a semicartilaginous tunic. There are two small valves in Otion, which are attached to the anterior aspect just above the brachial orifice. In Cineras they are five in number, two in the same situation as those of Otion, two along the terminal margin of the outer tunic, and one unpaired along the dorsal aspect. These are imbedded by their margins in the semi-cartilaginous tunic, and seem to be formed by it; calcareous matter being added to their margins in successive layers.

The ligamentous membrane, by which the valves in *Anatifa* are connected one with the other and with the peduncle, is strong but pliant. It is an extension of the outer covering of the peduncle. At the brachial orifice, it is reflected inwards to join the mantle. In addition to this, each valve has a membrane of its own, which closely invests its inner surface, and is not continuous with those of the other valves. The peduncle of this and the allied genera may be considered as a kind of developed ligament. If we regard the upper pair of valves as analogous to the valves of Acephalous Mollusca, the peduncle is found to be attached to them at points corresponding to the situation of the ligament in those shells. This organ is sometimes of great size. In the British seas it occasionally occurs two feet in length. Its epidermis is generally rough, wrinkled transversely, coriaceous, and elastic: Otion, however, has it very smooth and stiff, nearly cartilaginous, diaphanous. In some species it is so elastic as to admit of extensive lateral motion, and much elongation and contraction. These movements are effected by a layer of strong muscular tissue beneath the skin, within which there is a large organ, granular in its structure, regarded by some anatomists as the ovary. Burmeister is of opinion that the peduncle is merely an organ of support: and he suggests that the granular parenchymatous mass, which fills its interior, is destined solely for its own nutrition, which he seems to think is independent of the other parts of the animal. In most species, it is by its epidermis that the peduncle adheres. The peduncle presents still other varieties than those just mentioned. *Pollicipes villosus* has it covered partly with imbricated scales, and partly with a hairy coat; and *Pollicipes quadrivalvis* has its valves wholly encased in a large prolongation of the peduncle, which, on its upper surface, bears four valves arranged nearly in the same way as those of the opercule of the Balanids. The base of Coronula is closed by a strong fibrous membrane connected with the body of the animal only by a process of the epidermis. It is regarded by Burmeister as the analogue of the peduncle of the Lepads.

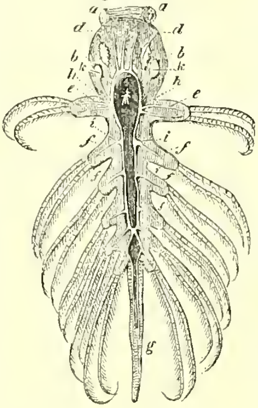
The cartilaginous tunic of *Otion Cuvieri*, at its summit, is enlarged into two large auriform appendages, hollow, having a crescentic orifice externally, and internally communicating with the visceral cavity of the animal; no organ is discoverable within them, but their cavities receive the terminations of a duct, which descends on the dorsal aspect of the body, in the groove of the dorsal valve, from the peduncle.

Of the mantle, as one of the tegumentary organs of the Cirripeds, little more need be said, than that it is generally a very thin transparent membranous sac, surrounding the visceral mass, open only at the brachial orifice, where it joins the epidermis and intervalvular ligament, and is reflected so as to form an inner lining for the visceral cavity. It has neither fringes of filaments, nor foliated processes. M. St. Ange describes another tunic of the visceral mass, which, he says, is continuous with the horny covering of the arms.

Locomotion.—Their base being permanently fixed, the principal motions of the Cirripeds are those of the arms, which seem to be subservient at once to the respiratory and to the digestive functions. But, as has just been mentioned above, the peduncle of Anatifa and other allied genera is moved both laterally and in the way of contraction and extension, and the valves, in the same animals, are so moved as to open and close the brachial orifice. The motions of the arms are, in many species, very rapid, and are performed with great regularity; proving the existence of a complete muscular apparatus both at their bases and within their numerous joints; but the parts are too minute to admit of a satisfactory examination being made of their structure. The Lepads have a strong transverse adductor muscle placed between their superior valves, just above the brachial orifice (*a*, *fig.* 340); this muscle seems to be every way analogous to the same organ in Acephala. Its action closes the brachial slit very accurately; while its relaxation admits of its being opened by the advance of the arms grouped together into the form of a wedge. This movement of the arms cannot be performed without the whole body being carried outwards; which is effected apparently by the contraction of certain delicate muscular fibres spread over the mantle, and attached around the margin of the orifice. Cuvier describes a similar set of fibres, " attached to the mantle opposite the insertion of the peduncle, by the action of which the general mass of the body is drawn deeply within the shell." This we have failed to observe in the species which have come under our notice. When the arms are fully exserted, they are separated one from the other, fan-like. This motion is probably produced by a muscular expansion, described by M. St. Ange as covering the visceral mass dorsally, the fibres of which are grouped into six bundles on either side, corresponding to the arms. The same observer describes also certain tendons which he found crossing one another at the median line; these are probably connected with another layer of muscles, expanded over the dorsal surface of the visceral mass, fitted to approximate the arms of either side towards one another. The muscles of the jaws cannot be satisfactorily examined on account of their minuteness. In the Balanids, the valvular opercule is moved by a set of muscles attached to the circle of shelly plates that surround the opening of the parietal cone. Its adductors, which close the aperture with great force, are attached to the extremities of the valves on either side. The visceral mass is, in the Balanids, fixed to the shell by three muscular bands, partly attached, around the mouth, to a process of the epidermis, and partly spread over the mantle.

Motility and Sensation.—The nervous system of the Cirripeds consists essentially of two nervous cords running along the abdominal surface, and swelling out into distinctly formed ganglions, at intervals corresponding to the feet-bearing lobes. The first pair of ganglions is situated above the œsophagus (*fig.* 339). They are united by a very short nervous cord.—From this supra-œsophageal ganglion and the uniting cord, there arise anteriorly three or four nerves, which are distributed to the muscular tunics. The principal nervous cords, leaving the first ganglion posteriorly, descend to encircle the œsophagus. In this course, they give off branches to the salivary glands and other neighbouring parts, and particularly, (as M. St. Ange has pointed out,) a nerve of communication with a small lateral ganglion (*k*, *k*, *fig.* 339) on either side, situated near the stomach and below the salivary organs. This is connected also with the second pair of ganglions. From this second pair, several branches arise, some of which go to the stomach, and two to the first pair of arms. The other arms receive only one branch each (*i*, *i*), which is divided into two, one for each of the jointed processes. In its course along the abdominal surface, the double ganglionic cord—the centre of the nervous system—lies immediately beneath the skin, between the bases of the arms. The fifth and the sixth pairs of ganglions have the appearance of being closely united. The tubular process, which terminates the anal extremity of the body receives two nerves, one from each of those going to the sixth pair of arms. Dr. Grant directs our attention to the fact that all the anterior parts of this system are very imperfectly developed compared with the posterior parts, and with the same parts in other articulated animals, which have their heads free, and organs of sense more complete.

Fig. 339.



The sense of touch is the only one enjoyed by the Cirripeds, so far as we can discover. The ciliated arms of some of the species are acutely sensitive: they are withdrawn immediately on being touched by any foreign body, and when the surrounding fluid is unfit for respiration. Some observers have also remarked that they shrink from a strong light brought to shine upon them suddenly. In the adult animals, there are certainly no organs which can be regarded as eyes; but, according to Mr. Thompson, what he believes to be the free-moving young have very well developed eyes, like those of some crustacea.

Some of the littoral Cirripeds, when left dry at ebb-tide, seem to be sensible of certain changes being produced in the state of the surrounding air by the approach of a living being to the place of their habitation. We have frequently remarked, on drawing near a spot densely peopled by the small acorn-shells that so abundantly cover most of our rocks on the sea-shore, a peculiar faint crackling noise, suddenly produced, gradually subsiding after the lapse of a few seconds, and not repeated until a movement was made towards another spot; and, on searching for the cause of this singular sound, we have satisfied ourselves that it is uniformly produced by the sudden closing of the opercules of the Balanids, which seem generally to remain open in ordinary circumstances. We have seen this motion again and again follow immediately the movement of the hand towards particular spots, (not, however, nearer the shells than twelve or fourteen inches,) so that we could not but conclude that the animal was made sensible, through the medium of the air, of the presence of some foreign body, and, fearing danger, closed its shell for self-protection; just as the limpet, warned of the approach of hurtful agents by the slightest touch of its shell, fixes itself more securely to its rocky footing. What the nature of the sense is which is thus used by the Cirripeds, we have no means of determining.

Digestion.—The minute swimming Crustacea appear to constitute the principal food of the Cirripeds. Sometimes, however, the shells of minute Mollusca are found in their stomachs, and Burmeister once found part of an annelid of unknown species. The food is carried towards the mouth by currents produced by the rapid motions of the arms, which, in most of the species, are constantly spread out and drawn in, alternately, with great regularity. The mouth is situated just at the bottom of the funnel-shaped cavity formed by the spread arms (*b*, *fig*. 340). In the Lepads its position is close to the transverse adductor muscle. Its jaws form a round protuberance, which presents itself very conspicuously immediately on separating the arms. It might almost be regarded as a head, so prominent is it (*fig*. 341, *b*, *b*); but we find it composed only of the lip and jaws, with their muscles. The lip over-arches the jaws; it is horny, and furnished with minute palpi. There are three pairs of jaws. The first or outer pair are thin horny plates of an oval form, fringed along their opposing sides with long stiff hairs. The other two pairs are curved and deeply serrated on their opposed surfaces. The middle pair bears a small palp on its lateral margin. In some species, a small tongue has been found. All these parts bear a close resemblance to the same organs in some of the Crustacea. The œsophagus is short; its lining membrane is somewhat horny, stiff enough permanently to distend the whole canal; before entering the stomach, its diameter is considerably enlarged. It receives the ducts of two salivary glands. The stomach (*c*, *fig*. 341) is capacious; externally, it presents an irregular mamillated surface, studded with numerous small prominences closely set, which are the outer surfaces of hepatic cells, formed in a layer of glandular tissue that closely invests the walls of the stomach. These cells communicate directly with its general cavity (*a*, *fig*. 342). There is no other organ that can be regarded as a liver.* Two cœcal appendages, also sacculated internally, and embossed outwardly, are attached to the stomach.

Fig. 340.

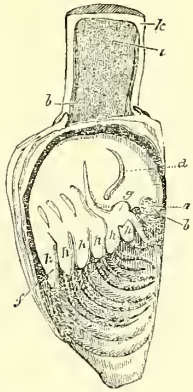
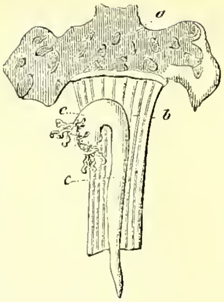


Fig. 341.

Fig. 342.



The intestine is wide, nearly without convolutions, and tapering towards the anus (*d*, *e*, *fig*. 341). In the Lepads the stomach is situated in that part of the visceral mass nearest to the peduncle; from which point the intestine runs on the dorsal aspect of the body, and terminates in the anus just at the base of the articulated tubular process. It is slightly dilated near the anus. The walls of the intestine are perfectly smooth and free from folds and duplications. The number of their tunics cannot be satisfactorily determined. M. St. Ange has described a singular piece of structure which he has found within the intestinal canal of certain Anatifæ (*c*, *c*, *fig*. 342). It is a kind of second intestine, which floats within the cavity of the one just described. It is nearly equal in length to the outer canal. Its upper extremity is expanded, funnel-shaped, with edges cut into fringed processes like the mouths of the Fallopian tube in vertebrate animals. These processes are lodged in the cells of the walls of the stomach, and furnish the only means of attachment to the outer walls with which the organ is provided. It thence tapers towards the anal extremity, where it is pointed and closed. Its walls are very thin and delicate. It is generally filled with alimentary matter, which must pass from its cavity by a kind of rumination, so as to enter the stomach a second time.

Circulation.—The sanguiferous system of the Cirripeds has not yet been fully investigated. Only the vessels of the arms, and a central canal, situated on the dorsal aspect of the body, have been discovered. Poli asserted that he saw a heart pulsating a little above the anus: but it does not appear that any other observer has made the same remark. Burmeister has searched, in vain, for a heart, in the large Coronula diadema. The vessels of the arms can be distinctly seen through the transparent integuments of the ciliated processes; there are, in each process, two vessels, one of which runs very superficially between the two rows of hairs. (*Fig*. 343.)

Cuvier regarded the anterior canal of the peduncle in Anatifa as the nourishing vessel of that organ.

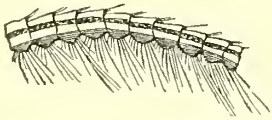
Respiration.—The principal organs concerned in respiration are, in the Lepads, certain tapering filamentary processes attached to the sides of the anterior part of the body, which are regarded as the branchiæ (*d*, *g*, *fig*. 340): in most of the Balanids, they assume the form of two leaf-like membranes with fringed margins, and are attached to the inner surface of

* Burmeister's recent researches have led him to conclude that both the Lepads and the Balanids have large livers. He has satisfied himself that the organs, regarded by Cuvier as the ovaries, and by more recent authorities as the testicles, communicate by ducts with the upper part of the intestinal canal, and not at all with the seminal vessels. Hence he supposes that they are lobes of the liver and not organs of reproduction. Our own dissections lead us rather to agree with Messrs. Wagner and St. Ange, who believe them to be the testicles.

the mantle. Professor Burmeister describes the gills of Coronula diadema as broad membranous expansions, of a semicircular form, attached to the sides of the visceral mass by a narrow pedicle. They are composed of two tunics arranged in deep and narrow transverse plaits. The number of the branchiæ in the Lepads varies from four to sixteen. They are composed of soft cellular tissue, and have a smooth surface.

The arms (*h, h, fig.* 340), which constitute so large a portion of the general mass of all the Cirripeds, and which form their most distinctive feature, must be regarded as subservient chiefly to the function of respiration; although, by producing currents in the water, which bring food within reach of the jaws, they minister also to the digestive function. In all the known species, both of Lepads and Balanids, these arms are twelve in number, six on either side, arranged symmetrically. Each arm is composed of a short fleshy peduncle, having three articulations, and two horny articulated processes, compressed laterally, of equal length, ciliated on their internal surfaces, and coiled up in a spiral of one turn. On their internal surface there is a coating of a black pigment in spots. Each joint is provided with a double row of hairs of different lengths. (*Fig.* 343.)

Fig. 343.



A part of one of the arms considerably magnified.

In Anatifa, the first pair of arms is thicker and stronger than the others; the sixth pair is the longest. Dr. Grant says, " the arms are not only minutely jointed to their extreme points, but, also, the innumerable fine cilia which project inwards from their surface are themselves minutely jointed, and by the aid of the microscope, we can perceive that these jointed cilia are also ciliated on their margins."

When the animal is at rest, with the valves of the shell closed, the arms are coiled up, and lie close to one another; but, at other times, circumstances being favourable to the performance of the function of respiration, they are extended simultaneously so as to project from the shell,—radiate and plumose in their arrangement. Many species extend and contract their arms with considerable rapidity, as often as forty or sixty times in a minute; the smaller species more frequently than the larger.

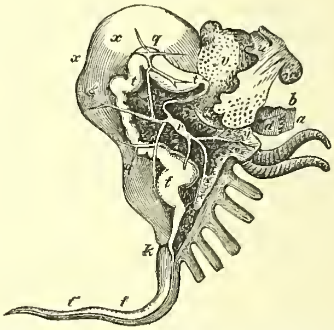
Considering how extensive the surface is which is exposed in the arms between the two rows of cilia, and that a vessel seems to run immediately beneath the delicate covering of these organs in that situation, it appears probable that the arms are very efficient agents in the function of respiration.

Secretion.— We have failed to ascertain satisfactorily the structure of the secreting apparatus by which the shells of the Cirripeds are formed. In the Lepads, the organs must be imbedded in the ligamentous membrane by which the valves are united: and in the Balanids, they are arranged in six rows along the outer surface of the mantle, and around the base; but, as in acephalous mollusca, they are too small to admit of their structure being particularly examined. The external surface of the mantle in the Balanids has also the power of secreting calcareous matter, with which to increase the thickness of the shell.

Reproduction.—It is not yet accurately determined what are the organs of reproduction in these animals. That which was regarded by Cuvier as the ovary in the Lepads, is supposed by Professor Wagner and M. St. Ange to be the testicle; while Professor Burmeister has satisfied himself that it is the liver. The extent, structure, and relations of the ovary are still doubtful. It is certain, however, that all the known Cirripeds are hermaphrodite.

The testicle, according to Professor Wagner and M. St. Ange, is a large granular organ (*y, fig.* 344), expanded over the sides of the

Fig. 344.



visceral mass, and around the digestive canal, from the stomach to the anus, passing even into the bases of the arms, immediately beneath the muscular tunics which cover the body on both sides. It is composed of numerous minute lobules, about $\frac{1}{300}$th of an inch in diameter in the common Lepads, soft, white, grouped together by branched ducts (*q, q, fig.* 344), which, after uniting into three or four principal trunks,* meet in a large central receptacle (*r*), somewhat analogous in relative function to the *vas deferens* of vertebrate animals. The seminal fluid passes from this central receptacle by a short and straight duct into a large canal (*t, t*), which may be compared to the seminal vesicle. It pursues a tortuous course towards the base of the tubular process, where (*k*) it is joined by its fellow of the other side, and enters the canal

* This description does not accord with the result of Professor Burmeister's researches. Instead of a regular series of branched vessels, he says that he met with nothing but an irregularly arranged mesh of thready fibres lying between what he believed to be the liver (described above as the testicle) and the intestinal canal.

of the process which forms a kind of caudal prolongation of the abdomen (*t′*, *t′*). This canal runs to the distal extremity, and opens by a minute orifice fringed with very fine hairs. In Otion Cuvieri the two canals are continued distinct to the very point of the process, where there are two openings.* The walls of the organ, which we have compared to the seminal vesicle, have a glandular structure, which Cuvier imagined to be the testicle. The researches of Professor Burmeister have led him to the same conclusion. He says it can be nothing but the testicle.† Cuvier, as well as Lamarck, regarded what we have called the testicle as the ovary, and believed that the ova were impregnated, in the course of their passage along the oviducts, by the seminal fluid flowing from the testicle investing these canals. The granular lobules of the true testicle, which were supposed to be immature ova, are found always in the same state, and what are more distinctly ova are found within the peduncle.‡

The lengthened tubular process (*t′*, *t′*, *fig.* 344), through which the excretory duct of the testicle passes, is articulated; the margin of each joint is fringed with minute hairs. In Otion and Coronula, Burmeister found large canals closed at both extremities, within the process, in addition to the ducts from the testicle. This organ is generally found after death bent upwards on the abdominal surface; but, during life, it is in continual motion. Its use is, probably, to carry the seminal fluid backwards beyond the current caused by the movements of the arms, in the event of there being mutual impregnation between separate individuals; or towards the mouths of certain ducts which communicate with the ovary within the peduncle, in case of self-impregnation taking place. In this view it must be regarded as the penis; and it is so called by the most recent authors on the subject—Wagner and Burmeister. Mr. Thompson calls it an *ovipositor;* and conjectures that, after their expulsion from the ovary, (understanding by this what we regard as the testicle,) the eggs are conveyed by it into the cellular texture of the pedicle. How they pass from this depository into the general cavity, where they afterwards form two or three foliated groups, he confesses himself unable to explain.

The peduncle of the Lepads was formerly regarded merely as an organ of support, and even Cuvier discovered within it nothing but what appeared to him to be a homogeneous pulp, surrounded by muscular tissue. But, at certain seasons of the year, at least, there are, very distinctly developed, throughout the greater part of the soft matter which constitutes the bulk of the organ contained within the dense cartilaginous and muscular tunics, certain oval granules, regular, and uniform in shape, and gradually increasing in size. Poli and Lamarck were of opinion that these were truly eggs, but held that they were originally formed in the granular organ surrounding the intestine, (now regarded as the testicle,) and merely deposited here temporarily. But the recent researches of Professor Wagner and M. St. Ange have rendered it probable that it is the ovary which is contained within the peduncle. The organ in question seems to occupy the whole of the peduncle within the layers of muscular tissue. It is separated from the visceral cavity by a fine membrane which lines that cavity, and is a reflexion of the mantle. A transverse section of the ovary shews the eggs most fully developed towards the outer margin, and scarcely formed in the centre. There are also seen in the same section two canals which run longitudinally through the organ, one near that side of the margin which corresponds to the anterior aspect of the body of the animal, the other in a similar situation on the dorsal aspect. Of these canals, the anterior is the larger; and it alone was described by Cuvier, who regarded it as connected with the circulating system. The other was first described by M. St. Ange, who satisfied himself that it is a true oviduct. In Anatifa, he traced it pursuing a straight course through the ovary, and leaving it as a perfect canal just at the posterior and inferior angle of the organ, thence passing on the outer surface of the lining of the visceral cavity, in the groove of the dorsal valve, and terminating in an orifice opening into the visceral cavity not far from the brachial slit.* We have found a structure exactly resembling the above in Otion, where, however, instead of opening into the general cavity of the visceral sac, the duct is bifurcated just between the two auriform appendages, into each of which one of the branches of the duct enters and opens. M. St. Ange found eggs in progress through this duct; and they are frequently found, arranged in groups or packets, two or three in number, within the cavity of the mantle. We have not yet seen them in the duct; but the whole structure of the parts in question seems to indicate their adaptation to the function assigned to them by M. St. Ange. This being the case with regard to Anatifa, it appears to be very probable that the use of the singular auriform appendages in Otion is to afford a convenient lodging for the eggs before the young are hatched. Their deep sinuosities and folds seem to adapt them admirably to this purpose. Packets of eggs, however, are found within the cavity of the mantle in this species as in others. According to Burmeister, these packets are unattached, excepting in the earliest stage of development; but Wagner has generally found them fixed to a process of the mantle, situated near the adductor muscle of

* Burmeister, Beiträge, p. 46.

† Op. cit. p. 44.

‡ Professor Wagner is satisfied that nothing but the discovery of spermatic animalcules can assure us against error in our attempts to determine what is the testicle.

* Professor Wagner says, "at the base of the dorsal valve there exists a slit in the mantle which leads into the canal that runs through the peduncle. I presume that this canal serves as an oviduct, and that the slit is analogous to the opening of the branchial canal in the bivalves," (in Archiv für Anat. Physiol. &c. von D. J. Müller, 1834, No. 5, quoted in Ann. des Sc. Nat. iv. n. s.) We are not aware what species was anatomized by Professor Wagner.

the shell; which process is, at times, so much elongated as to admit of the eggs hanging out in groups from the brachial aperture, beyond the extremities of the arms. Burmeister has observed that, after the escape of the embryo, the shells remain connected with the parent, forming a loose net-work. This author seems to regard these groups of eggs within the mantle, and the tissue in which they are imbedded, as constituting the true ovary. In each of the individuals of Anatifa striata which came under his observation, he computed that there were about 4000 eggs in the ovary. Mr. Thompson calls these groups of ova *conceptacles;* and says that "each has a separate attachment at the sides of the animal to the septum, which divides the cavity occupied by the animal from that of the pedicle."* The retention of their ova, grouped in separate packets on the surface of their bodies, after their expulsion from the ovary, constitutes another point of resemblance between the Cirripeds and Crustaceous animals.

With regard to the anterior canal within the ovary, little has yet been determined. We have particularly examined it in Otion, and find that, like its fellow of the dorsal aspect, it leaves the ovary at its inferior edge, whence it opens into a small cavity situated between the intervalvular ligament and the lining membrane of the visceral cavity. We have not succeeded in discovering any orifice in the walls of this cavity, although, from the results of some of our experiments we think it probable that there exists a small one just above the brachial slit. If so, is it not likely that this is the passage intended for conveying the fecundating liquor from the orifice of the tubular process connected with the male organs to the ovary? When the body is exserted through the brachial slit, the point of the process can easily be brought into contact with the outer surface of the cavity above described.

The development of the egg and the young of the Cirripeds has recently become an object of interesting inquiry in consequence of the novel results announced by Mr. J. V. Thompson in his "Zoological Researches," (1830, 4th Memoir.) This gentleman has published an account of observations made on what he believed to be the young of Balanids, from which he concludes that, on their first exclusion from the egg, they closely resemble some of the branchiopodous crustacea,—that they possess the power of free locomotion through the water by means of setiferous arms projecting from within a bivalve shell,—and that they have very obvious pedunculated eyes. Minute animals, bearing these characters, and having some resemblance to species of the genus Cypris, were placed by Mr. Thompson in a glassful of sea-water. Soon after, on looking for them, he could not find them in the water, but he found in their room several very young balanids, which, from the appearance they presented, he concluded to be really the same animals that he had originally placed in the water, changed by metamorphosis. Mr. Thompson has not seen the change actually going on, but he has satisfied himself that what he regards as the free-moving embryo fixes itself by a spot on its dorsal aspect between the two shells, which spot can be seen during its free state. When fixed, the base of adherence appears to be broad like that of an Actinia: from this it rises in a conical form, truncated. The flat sides of this cone are coated with six shelly plates, so arranged as to leave a large space in the middle uncovered. This space is closed by the old shells of the embryo state, which are made to move up and down as the opercule does in the adult animal, admitting of the egress and ingress of the arms at the animal's pleasure. Through this shell two large black spots like eyes can be distinguished. Mr. Thompson found in the young of the Balanids, six pairs of arms, cleft; each arm with two articulations. The first casting of the shell, after the animal has fixed itself, is followed by an increase in the number of articulations in each arm; and this number is further added to at every succeeding shell-casting. Even the old full-grown animals, according to Mr. Thompson, cast their shells.

Very recently Mr. Thompson has made a still more satisfactory series of observations on the development of some of the Lepads, of the genera Cineras, Otion, and Lepas. These he obtained from the bottoms of vessels in the harbour of Cork. They hatched eggs in large numbers, and afforded him the means of ascertaining, entirely to his own satisfaction, that, at its first exclusion from the egg, the Lepad, like the Balanid, is a *natatory crab.* He found a considerable difference between the *larvæ* of the two classes. The newly-discovered one of the Lepads he describes as "a tailed monoculus, with three pairs of members, the most anterior of which are simple, the others bifid, having its back covered by an ample shield, terminating anteriorly in two extended horns, and posteriorly in a simple elongated spinous process."

The general appearance of this larva is not unlike that of the *Argulus armiger* of Latreille.*

Very recently Messrs. Audouin,† Wagner,‡ and Burmeister,§ have corroborated the statements and supported the views of Mr. Thompson. Professor Burmeister has detailed the results of his observations with great minuteness. It appears that they were made chiefly on individuals of Anatifa striata, procured in the North Atlantic Ocean, and preserved in spirits; partly also on Lepas anserifera. (Linn.) The results of these observations have led Professor B. to divide the development of the Cirripeds into five stages or periods. The *first* of these is the state of egg; the *second* is that of

* Phil. Trans. 1835, 356.

* Phil. Trans. 1835, pt. ii. 355. "Discovery of the Metamorphosis in the second type of the Cirripeds," &c.

† Ann. des Sc. Nat. n. s. iii. 31.

‡ Müller's Archiv, No. 5, 1834, and Beiträge zur vergleich. phys. des Blutes. Leipzig, 1833.

§ Beiträge zur Naturgesch. der Rankenfüsser. Berlin, 1834.

free locomotion; the *third* is that in which the young becomes encased in a shell, and fixes itself; in the *fourth* stage, the young gradually assumes the characters of the adult; the *fifth* stage is that of perfect development.

First stage.—The egg. Its outer covering is a very delicate membrane. The yolk is yellowish-red, clouded, and marked with two rows of small spots, globule-like, distinct at one end, running together at the other. The eggs in the central parts of the ovary are considerably further advanced than those in the circumference. Through the transparent covering of the egg the general form of the embryo can be seen.

Second stage.—In this stage the young Cirriped resembles the fry of *Cyclops* or *Daphnia* in its external characters. It is provided with two long antennæ and three pairs of feet (arms?) placed along its ventral surface.* Each foot of the first pair is single, and is furnished with bristles at its free extremity. Each of the other pairs is divided into two members, also tipped with bristles. The posterior part of the body is tapering, compressed, and slightly bifurcated at its extremity, where it is beset with bristles. No eyes could be seen in this stage, but Professor Burmeister nevertheless conjectures that they really do exist. The appearance of two rows of small globules on the surface of the body continues to present itself, but here they are more numerous, although not larger. The middle part of the body is clear and transparent.

Third stage.—Materials for the description of this stage were obtained by Burmeister from the examination of only one individual, which was found attached to the frond of a fucus hard by the bases of some adult individuals. The shell, in this the first stage of its growth, is of leathery consistence, and formed of one piece, placed dorsally. A fleshy protuberance serves as the peduncle. The organs by which the young animal fixes itself are evidently the long antennæ situated near the mouth. Behind these are placed the very large eyes. Burmeister satisfied himself of the existence of a single transparent cornea, and saw behind it a round black spot, but no lens. The two eyes are very closely approximated by their bases. Both the eyes and the brownish contents of the alimentary canal can be distinguished through the translucent shell. In the structure of the posterior part of the body there is no great change from the former stage. Each arm of the first pair is single, and consists of three articulations, of which the basilar is the greatest: the smallest and terminal one bears four long stiff bristles. The arms of the following pair are not single, but each is divided into two small articulated processes. The little globules of the two former stages are not discernible in this.

* The circumstance of there being a smaller number of arms in the young than in the adult, reminds us of the same being the case in several of the Branchiopodous Crustacea; and the want of the shell in young Cirripeds seems to point out a closer analogy between them and Crustacea, than between them and Mollusca, the young of which are covered with shell in the egg.

Fourth stage.—This stage was observed by Professor Burmeister in the *Lepas anatifera* from the coasts of Chili. All the individuals examined were about three-fourths of a line in length. Soon after the animal fixes itself the old integuments are thrown off. The eyes and the antennæ are entirely cast off along with these. After this process had been completed, the space within the mantle was found to be filled with a granular pultaceous mass, at first occupying the greater part of the cavity of the shell, and covering all the young animal. This appeared to M. Burmeister to be the same that is found in the pedicle of the older animals, and to resemble closely the matter contained within the cavities of the shells of Coronulæ and other Balanids. It is by a sack-formed process of the mantle filled with this yellowish matter that the peduncle is first formed. At the time of the animal's fixing itself the shell has no calcareous points, but in the course of this stage it becomes firm and gradually more and more solid. There are now six pairs of feet, each of three articulations, and terminated by bristles. A small tail of two articulations also appears, the rudiments of which, however, can be detected in the former stage. In the *fifth stage* the process of development is completed.

It must be admitted that the evidence in favour of Mr. Thompson's opinions on this subject is by no means conclusive. There is still wanting a series of minute and careful observations on the first appearance and motions of the embryo immediately after its exclusion from the egg; and nothing but the results of such a series can settle the question as to whether there be a real metamorphosis or not.

Mr. Gray's observations have led him to conclude that no great changes of structure, such as Mr. Thompson's views presuppose, actually take place; although, in examining the mature egg of *Balanus Cranchii*, he found the appearance of the embryo nearly the same as is described by Burmeister as being that of the Lepads in the second stage of development. The egg of this Balanid Mr. Gray ascertained to be one-fiftieth of an inch in length. He describes the inclosed animal as being of an ovate form, tapering at one extremity, truncated and ciliated at the other; bearing a general resemblance to the adult animal, but furnished with only three pairs of ciliated arms; the base of each arm being two-jointed. He found only one lengthened process attached to the lower pair of arms; but, connected with the two upper pairs, two fusiform, thick, articulated and ciliated processes, similar to those of the anterior part of the perfect animal, but less elongated. He saw no shelly covering.*

We have not yet had proper opportunities of devoting attention to this interesting subject so far as observations on the living animals are concerned; but we have no doubt of its very soon meeting with a clear and satisfactory elucidation; meanwhile we may remark that the structure of the embryo within the mature egg

* Proceedings of Zool. Soc. Lond. 1833, pt. i. 115.

(about which there can be no doubt) is such as strongly to indicate its adaptation to free locomotion; and that, after a review of all the observations that have been published on the subject, we are inclined to conclude in favour of Mr. Thompson's opinion that, in the early stages of its development, the young Cirriped really enjoys locomotive powers, and then undergoes such changes of structure as are required to fit it for its altered circumstances in adult age.

Bibliography.—*Leeuwenhoek*, Opera, iii. 472. *Lister*, Exercit. anat. 1696, p. 96. *Cuvier*, Mém. pour servir à l'histoire des Mollusques, 1817. *Lamarck*, Anim. sans vertèbres, v. 377. *J. V. Thompson*, Zoological researches, 1830; Fourth Memoir; and Phil. Trans. 1835, 355. *Wagner*, in Archiv für anat. physiol. &c. von D. J. Müller, 1834, No. v. *Burmeister*, Beiträge zur Naturgeschichte der Rankenfuesser, Berlin, 1834. *Martin St. Ange*, Mémoire sur l'organization des Cirripèdes et leurs rapports naturels avec les animaux articulés, Paris, 1835.

(John Coldstream.)

CIRRONOSIS. (Κιῤῥος, *fulvus*; νοσος, *morbus.*) In a memoir published by M. Lobstein in the first volume of the *Répertoire d'Anatomie and de Physiologie** for the year 1826, this term was applied to what that author considers to be a disease affecting the fœtus at an early period of intra-uterine life. The essential characteristic of the malady consists in the serous or transparent membranes being dyed of a beautiful deep golden yellow colour. "The disease is," says M. Lobstein, "an internal jaundice of the peritoneum, of the pleura, of the pericardium, of the arachnoid, differing from the ordinary jaundice, in that it does not affect the parenchymatous cellular tissue of organs, nor the subcutaneous tissue, nor the skin, the usual seats of that disease."

Lobstein published the first account of the occurrence of these appearances in two five-month fœtuses, in his Rapports sur les travaux executés à l'Amphithéâtre d'Anatomie de Strasbourg.† Since that time additional cases were presented to his attention, from which he ascertained that the yellow staining was not confined to the serous membranes only, but also was found in the nervous tissues, especially those of the spinal marrow and encephalon. By the aid of the microscope he perceived that the substance of the marrow seemed to be composed, as it were, of small grains of a lemon yellow colour, mixed with a white and pulpy substance, as if a very fine gold-coloured powder had been intimately mixed with a soft and semi-transparent jelly. In these cases the thoracic portion of the sympathetic also exhibited a similar colour, and the ganglia were somewhat swollen, and it was ascertained by the microscope that the stain was equally inherent in the nervous substance of the ganglia as in that of the spinal marrow.

It is impossible to remove the yellow stain from the structures in this condition either by ablution or immersion for any length of time in alcohol or water. The intensity of the colour was not diminished in preparations which had been preserved in spirits for seventeen years, neither was it affected by the action of light.

The difficulty of accounting for the phenomena which constitute this disease of the embryo is much increased by the fact that cirronosis has hitherto been observed only in three or five month fœtuses. As at this period the biliary secretion has not begun to be formed in the usual way, we cannot attribute the occurrence of this disease to any of the causes which give rise to ordinary jaundice, so commonly met with in the fœtus at and shortly after birth. There seems, however, to be no reason to doubt that the elementary constituents of the biliary secretion may already exist in the blood at an early period of intra-uterine life, and that from them the stain may have been communicated to the serous membranes and nervous tissues. But we cannot but express our concurrence in the opinion of Andral, that cirronosis differs only in situation from the ordinary icterus infantum or neonatorum; there being this remarkable distinction also, that the tissues which are the seat of the colour in cirronosis are rarely affected in jaundice.

Although the observations of Lobstein were first published ten years ago, I do not find that they have been confirmed by any subsequent observer. The preceding account, therefore, of this disease rests entirely upon his authority, and is drawn up chiefly from his paper in the *Répertoire* already referred to.

(R. B. Todd.)

COLLOID. See Scirrhus.

CONCHIFERA. Fr. *Conchifères.* When we take a general view of the organization of the extensive series of Mollusca, two principal classes are readily distinguished, one of which has been raised to the rank of the primordial division of the animal kingdom by Lamarck; this class, comprising the whole of the Acephala of Cuvier, as well as the Brachiopoda, has received the name of Conchifera.

The mollusks included in the class of Conchifera present peculiar characters which prevent their being confounded in any point of the series with the other classes of the same sub-kingdom. They are all contained within a bivalve shell, generally articulated after the manner of a hinge; to this shell the animal is attached by one or several muscles, and the shell itself is secreted by a fleshy envelope, generally thin, but having the edge thickened, to which naturalists agree in giving the name of *mantle*. The animal, of a structure more simple than other mollusks, has no head; the mouth is pierced at the anterior extremity and is the entrance to organs of digestion, consisting of a stomach, an intestine of different lengths, an anus, and an organ

* Rep. d'Anat. et de Phys., t. i. p. 141.
† Page 26, ed. in 4to.

for secreting bile. Circulation is performed by means of a heart generally symmetrical, the ventricle of which surrounds the rectum. Respiration is effected by means of four branchial leaflets, equal in size and symmetrical, arranged on either side of the body. Generation is simple; the Conchifera are endowed with hermaphrodism adequate to the continuation of the species; every individual has an ovary included among the general mass of the viscera. The nervous system does not form a complete ring around the œsophagus; ganglia are found towards the anterior and posterior parts of the animal, and lateral and very long filaments form a ring within which the visceral mass is included.

Before entering upon the more particular description of the organs which have just been mentioned, it is essential as a preliminary to institute some order among the members of the class Conchifera, to throw them into a few grand divisions by which the labour of description, in many particulars, will be very much abridged.

Lamarck divided the Conchifera into two grand orders, *Dimyaria* and *Monomyaria*. We are of opinion that this division may be preserved with some slight modifications; and, farther, that it is necessary to establish a third order equal in importance to the two others, and including the Brachiopoda. The anatomical inquiries of Cuvier, and those, still more recent in their date, of Mr. Owen into the structure of the Brachiopoda will not allow us any longer to regard these animals as pertaining to the family of monomyary Conchifers. These inquiries also prove that Cuvier, in forming the Brachiopoda into a particular class of Mollusca, disjoined them in too great a degree from their congeners. It is from regarding both of these views as carried too far, that we have been led to propose a new division which to us appears to be called for, and to be preferable to either of the others; this is to restore the Brachiopoda to the type of proper Conchifera, and to establish a third order of this family for their especial reception, to which the title of *Polymyaria* might be given. Instead of placing this order at the end of the Conchifera, however, it appears better to set it at the head, especially if the analytic method of Lamarck be adopted as the basis of the classification. The Conchifera we should, then, propose to arrange in the following order:

CONCHIFERA.

- First sub-class. BRACHIOPODA, or POLYMYARIA ....
  - 1st sub-order: valves articulated.
  - 2nd sub-order: valves free.
- Second sub-class. DIMYARIA
  - Order 1st. The lobes of the mantle more or less united
    - 1st sub-order: shell regular.
    - 2nd sub-order: shell irregular.
  - Order 2nd. The lobes of the mantle disjoined . . .
    - 1st sub-order: shell regular.
    - 2nd sub-order: shell irregular.
- Third sub-class. MONOMYARIA
  - 1st order: a foot.
  - 2nd order: no foot.

The organization of the Brachiopoda being more simple than that of the other Conchifera, renders it proper to place this order at the beginning of the class. The Dimyaria having an organization somewhat less complex than the Monomyaria constitute an intermediate order, which is the most numerous of the three; the Monomyaria terminate the series.

To facilitate the comprehension of the brief descriptions which we shall give of the different parts of the Conchifera, it seems necessary to state precisely the position in which the animal must be placed in order to be suitably observed. The animal, then, is supposed to be walking before the observer, included within six planes to which its different parts are referred. The head or the oral aperture indicates the anterior extremity of the creature. This extremity is directed forwards, its posterior extremity backwards. The back corresponds to the superior plane; the belly and foot correspond to the inferior plane, and the flanks of the animal to the lateral planes, one of which is to the right, the other to the left. The two accompanying figures (*fig.* 345) will suffice to give an idea of the relations of one of these animals to the different planes within which it is supposed to be included.

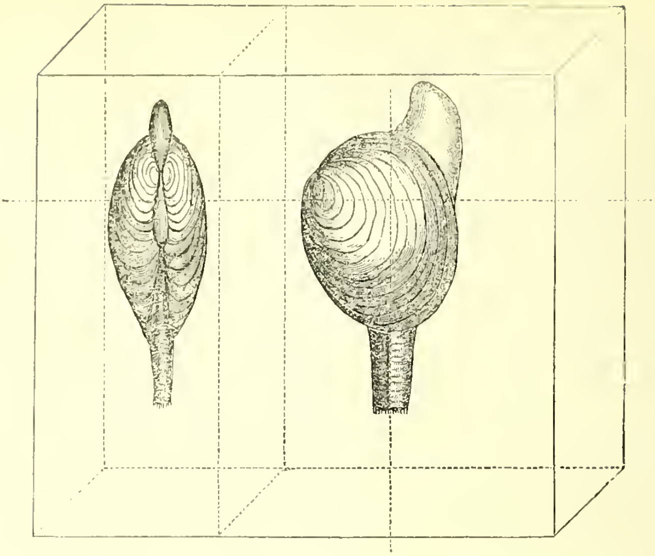
The organization of the Conchifera is simple enough. The researches of anatomists have shown that these animals are provided

with organs of
- digestion,
- circulation,
- respiration,
- generation,
- and (in the greater number) of locomotion;

with a skin or envelope common to the whole of these organs; and a nervous system bringing the different systems into mutual relation with each other.

Of the organs of digestion.—In the Conchifera, as among other animals, these organs begin at the oral aperture. This aperture

Fig. 345.



(*a*, *fig*. 346) placed at the anterior part of the animal is deeply hidden between the foot (*b*, *fig*. 346), and the anterior retractor muscle (*c*) in the Dimyaria, and under a kind of cowl formed by the mantle in the Monomyaria. The mouth is in the form of a transverse slit, comprised between two lips, generally thin and narrow, as in almost all the Dimyaria, or lobated and digitated, as in some of the Monomyaria, (*a*, *fig*. 348). The lips extend on either side in the form of two flattened smaller appendages, more or less elongated, occasionally truncated, streaked or laminated on their internal surface, and to which the title of *labial palps* has by general consent been given, (*d*, *fig*. 346, *c*, *fig*. 348.)

Fig. 346.

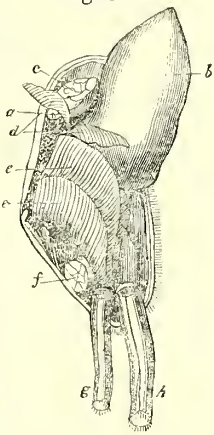
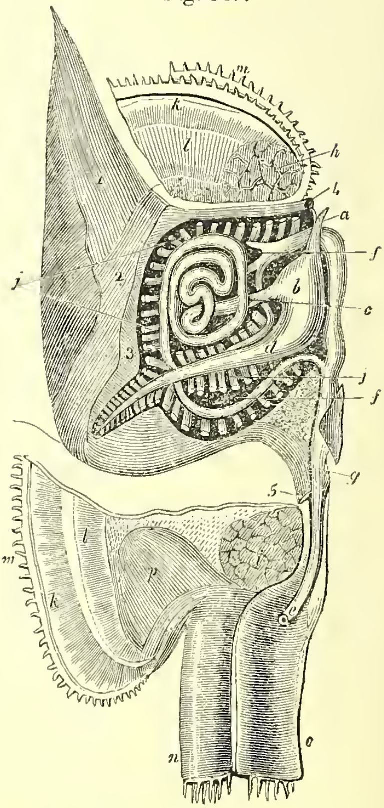


Fig. 347.



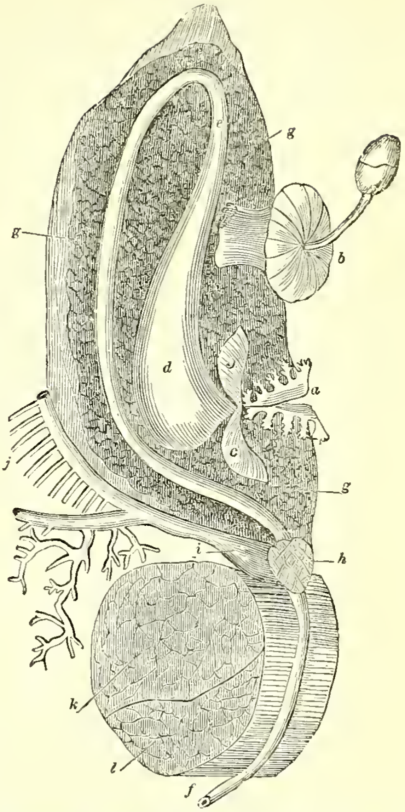
The mouth in the Conchifera never presents any part that is hard. In the greater number of these animals it terminates without any intermediate passage in a stomach, the form of which is subject to but little variety. When there is an œsophagus (*a*, *fig*. 347), it is variable both in point of length and capacity; it has nothing constant, relatively to the other distinctive characters of the groups established among the conchifera generally: thus it either occurs or is wanting indifferently among the individual members of the dimyarian and monomyarian families.

The stomach (*b*, *fig*. 347, *d*, *fig*. 348) is a membranous pouch, commonly pear-shaped, sometimes globular, rarely elongated and narrow. When the œsophagus exists, it opens into the upper part of the stomach; but when that canal is absent, the mouth terminates directly in the stomach. Examined internally, the stomach presents several depressions irregularly dispersed over its surface, by means of which the bile is brought into its cavity; it is on this account that these minute depressions have received the name of the *biliary crypts*. The intestine (*c*, *fig.* 347, *e*, *fig.* 348) arises from the posterior wall of the stomach, and a very singular apparatus is occasionally found in its vicinity (*d*, *fig.* 347), the use of which is not yet determined. It consists of a small appendage which may be compared to the vermiform process of the cœcum in the higher animals; it communicates with the stomach, and is filled by a horny process or stylet of different lengths and thickness, according to the genera and species examined. The anterior extremity of this body is attached to the parietes of the stomach by means of small extremely thin and irregular auricular processes *(oreillettes)*. It is to be presumed that quantities of the food may fall during the act of digestion between the parietes of the stomach and the horny body, by it to be pressed or bruised in some particular manner. Yet when those conchiferous animals which are furnished with the apparatus just mentioned, are examined by dissection, no particle of food is found in such a position. We may therefore be allowed to conjecture that this part accomplishes some other purpose in the economy of the conchifera. Whatever this may be, it must, we should imagine, be connected with the function of digestion.

The intestinal canal in the conchiferous Mollusca is generally slender, cylindrical, and from one extremity to the other almost always of the same diameter. After having made a variable number of convolutions within the substance of the liver and the ovary, the intestine comes into relation with the dorsal and median line of the animal's body. It continues in this direction to the posterior extremity, there to terminate in the anus (*e*, *fig.* 347, *f*, *fig.* 348); the whole of this dorsal part of the intestine is named *rectum*. The rectum is generally longer in the Dimyaria than in the Monomyaria, because the anus is found above the superior adductor muscle in the former, whilst in the Monomyaria the rectum twists round behind the central muscle to terminate in an anus which floats between the edges of the mantle.

The liver (*f*, *fig.* 347, *g*, *fig.* 348) is a bulky organ enveloping the stomach and part of the intestine. It pours the product of its secretion directly into the stomach by means of the biliary crypts. The liver alone constitutes a very large portion of the visceral mass, and consequently of the body of the animal; it consists of a great number of follicles connected together by means of lax and extremely delicate cellular membrane; this structure renders the organ very easily torn. We shall see by-and-bye that it is traversed in

Fig. 348.



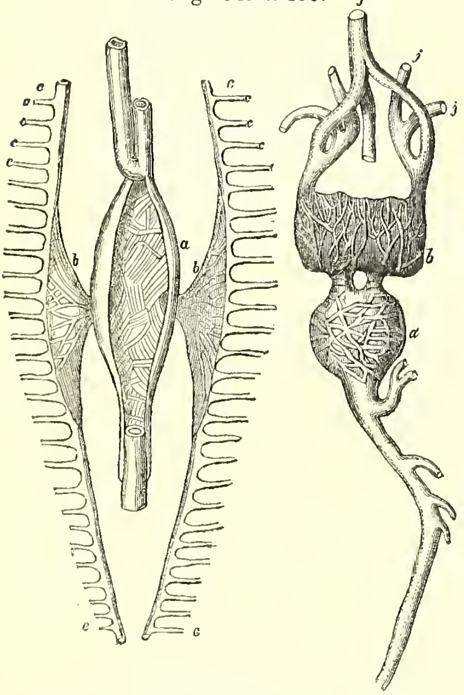
the greater number of mollusks by several muscles belonging to other parts, an arrangement which contributes to support and give it greater strength.

The exposition which has now been given of the structure of the organs of digestion, affords a ready explanation of all that bears upon this function in the conchiferous mollusca. These animals not having the mouth armed with any hard part are unable to seize and swallow any kind of solid food, so that in general nothing more is found in their stomachs than segregated particles, proceeding without doubt from the decomposition of aquatic animals and plants. The lips, and unquestionably the labial palps also, are destined to give the animal perception of the aliment it takes. Once in the stomach, this aliment, impregnated with bile and probably also with a gastric juice secreted by the lining membrane of this pouch, is subjected to a first digestive elaboration; it next passes the pylorus when it exists, and then traverses the intestinal canal and supplies to the absorbent system the elements necessary to the nutrition of the animal.

It does not appear that there is any particular system of *absorbent vessels* in the conchiferous Mollusca; the veins perform the office of absorbents, and they transmit without any intermedium, and without their undergoing any glandular elaboration, the fluids absorbed to the general current of the circulation. After having thus had all the nutritious elements it contains abstracted, the alimentary mass, having reached the rectum, there commonly presents itself under the form of minute globules; it is soon afterwards expelled through the anus.

Organs of circulation.—The organs of circulation in the acephalous Mollusca consist of two vascular systems forming together a simple circuit, namely, a ventricle and an arterial system, and a venous system and two auricles. The ventricle in the majority of acephalous mollusca is single, symmetrical, situated in the dorsal median line of the body, and rests upon the rectum, which it embraces in its evolution (*g*, *fig.* 347, *h*, *fig.* 348) on every side so closely, that the intestine appears to pass through it. It is to be presumed, however, that the intestine does not pass immediately athwart the heart, but that this canal is only embraced so intimately by the central organ of the circulation, that it is impossible to separate without tearing them. The ventricle, which is regular and symmetrical in the greater number of the genera (*a*, *fig.* 349) is irregular and unsymmetrical in the Ostracean family, (*a*, *fig.* 350). It is generally elongated and fusiform;

Figs. 349 & 350.



its parietes are thin, formed of muscular fibres variously interlaced, and often projecting internally. From either extremity issues one of the two main arteries of the body, the one superior giving branches to the whole of the anterior parts of the animal; the other posterior supplying branches to the principal viscera,—the stomach, liver, intestinal canal, and ovary. Many superficial branches penetrate the mantle, and may be observed ramifying more especially upon the thicker parts which constitute its edges.

When the back of the animal is very broad, and as a necessary consequence of this structure, the branchiæ of one side are at a considerable distance from those of the other side, we find, as among the Archidæ, that there are then two ventricles (*a*, *a*, *fig.* 351,) and two auricles (*b*, *b*, *fig.* 351) to secure the perfect performance of the important business of circulation. This interesting modification of the organs of circulation is of slight significance as regards the mere results of the function, for it still continues no more than a simple circuit, exactly as if it were effected by a single ventricle.

The auricles are two in number (*b*, *b*, *figs.* 349 & 351, *i*, *fig.* 348) in the whole of the genera of Conchifera except those of the family of the Ostracea, in which there is no more than a single irregular auricle (*b*, *fig.* 350), just as there is but one ventricle. The most general figure presented by the auricles is the triangular. They communicate with the ventricle by one of the angles of the triangles, and they receive the blood of the branchiæ by the most extensive of their three sides. These organs are altogether membranous; in their interior, however, we discover, with the aid of the magnifier, a great number of small fibrous fasciculi, by means of which the regular contraction of the ventricles appears to be effected.

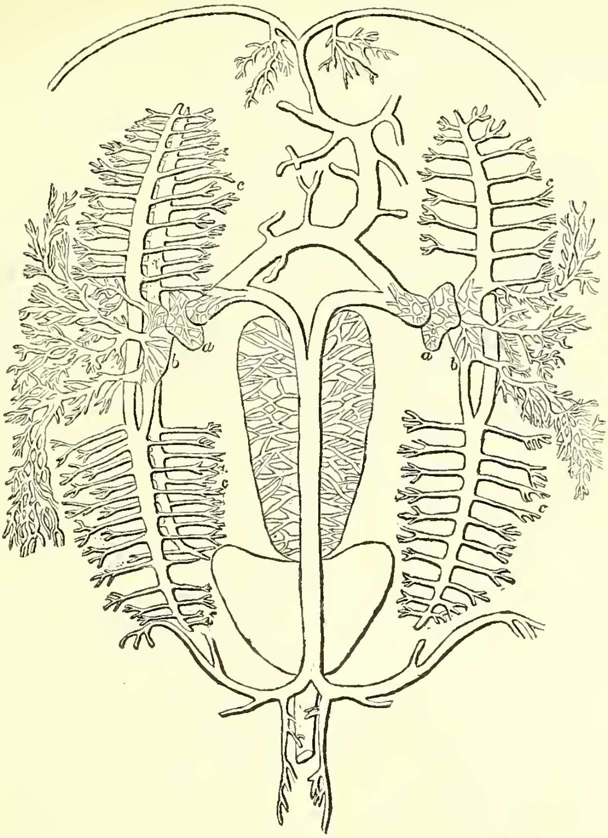
The venous system is of very considerable magnitude. In his magnificent work, Poli* has given a very satisfactory account of its anatomy. It is more particularly remarkable in the Archidæ, the Pinna, &c. It is destined to receive the blood of the general circulation; it is also destined to collect the whole of the fluids absorbed, and to direct these towards the branchial apparatus, in which the blood with these added fluids undergoes a fresh elaboration. It is after having traversed the branchial vessels (*c*, *c*, *c*, *c*, *fig.* 349, 351, *j*, *fig.* 348) that the blood revivified is carried towards the auricle by the pulmonary veins, from whence it is sent to the ventricle, and by it forced anew to perform the round of the arterial circulation.

The blood in the Conchiferous mollusks is colourless, or of a bluish white, very different from the hue it presents in the vertebrata; it is but slightly viscid, and when it coagulates exhibits but a very small quantity of crassamentum or solid matter.

Circulation then is an extremely simple function in the Conchiferous mollusks: an aortic ventricle gives the blood impulse enough to carry it through the two systems of vessels, to expel it from the heart and to bring it back again to the auricle. In other branchiferous animals, the auricle is sometimes adapted to give the blood a new impulse when it is about to pass through the branchiæ; here, on the

* Testacea Utriusque Siciliæ, fol. 3 tom.

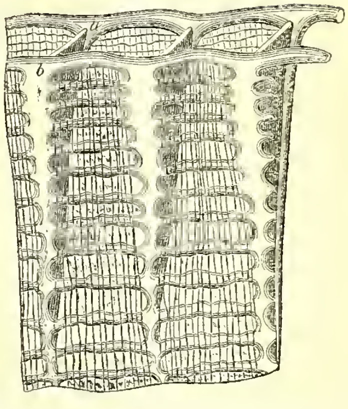
Fig. 351.



contrary, the auricles do not receive the blood until it has been exposed to the revivifying influence of the organs of respiration.

Of the organs of respiration.— The whole of the Conchiferous mollusks respire by means of branchiæ (*e, e, fig.* 346). These organs are variously disposed according to the form of the animal. They are symmetrical; and in almost all the genera there are two on each side. The branchiæ generally present the form of membranous leaflets, of a quadrangular shape, though often unequal. They are broad and short when the animal is globular, elongated and narrow when the animal is lengthened in its general form. In the greater number of genera the branchiæ are formed of two membranous layers or laminæ (*a, b, fig.* 352) within the substance of which the branchial vessels descend with great regularity. In several genera, as the Archidæ and Pecten, the branchial vessels, instead of being connected parallel to one another within the thickness of a common membrane, continue unconnected through their entire length, and they are thus formed of a great number of extremely delicate filaments attached by the base within a membranous pedicle, in which the branchial veins pursue their way towards the auricle. In a great many families and genera the branchiæ of one side have no communication with those of the opposite side; in some others however, as in the genus Unio, the four branchial laminæ meet under the foot, and the whole of their vessels empty themselves into a venous sinus of considerable size.

Fig. 352.



A remarkable phenomenon is observed in a great many of the Conchiferous mollusks: the eggs on escaping from the ovary, instead of being cast out altogether, are deposited between the two membranes of the branchial laminæ, and there undergo a kind of incubation, during which they acquire a considerable size. In some genera, such as the Unio, the shell is even developed within the egg before this is cast loose from the branchiæ, and this circumstance has led several anatomists to mistake these small shells for parasites. As in all the other animals having branchiæ, the organs of respiration are destined to restore to the blood the oxygen which it had lost in its circulation through the body. This necessary element to the maintenance of life is restored to it during its passage through an organ contrived so as to bring it almost into contact with the ambient fluid in which a considerable quantity of atmospheric air, and consequently of oxygen, is found dissolved.

Organs of generation.—The organs of generation are of extreme simplicity in the Conchiferous mollusks. They consist of an ovary included in the visceral mass. Not a trace of any other organ of generation can be detected, and the Conchifera must therefore be allowed to possess what has been called sufficient hermaphrodism, generation in them taking place without coition. The ovary is a glandular mass situated at the superior and posterior part of the body; it is in connexion with the liver; and it often receives a portion of the intestine, if it happens to be developed laterally between the two fleshy laminæ which form the walls of the foot. In the siphoniferous acephala having the foot short and rudimentary, the ovary, in its state of complete development, forms a very great part of the abdominal mass, amid which it is easily distinguished by its soft consistency and yellowish white colour. In those acephala in which the siphon is short and the foot well developed, the ovary forms a mass less prominent at the superior and posterior parts of the viscera. In the Conchifera monomyaria the ovary resting upon the central muscle is situated in the upper and posterior part of the body, and in its state of development constitutes a whitish mass of considerable size, which is readily seen in the Ostracea through the walls of the mantle. This ovary occupies the whole superior part of the animal, and it is seen descending along the lateral and posterior parts when the animal is examined at the time of laying its eggs; a rent in the ovary allows a fluid of a milk-white colour to escape. This fluid under the microscope is seen to contain a very great number of small whitish granules, each of which is an egg capable of reproducing an individual similar to that from which it derives its origin.

There is a singular genus placed by the generality of writers in alliance with the Oyster, and designated by the name of Anomia, in which the ovary forms no part of the common mass of the viscera, but extends between the two walls of the mantle, which it separates in proportion as it increases in size. This position of the ovary in the substance of the skin is analogous to what is observed in the Terebratulæ, in which the ovary is divided into four segments comprised within the substance of the mantle and in the direction of the principal branchial vessels.

Notwithstanding the minute dissections which have been made of the acephalous mollusks, there are a great many in which the oviduct remains unknown. In two of these animals in which it has been sought for in vain, it has yet been seen running towards the middle and anterior part of the branchiæ, and opening to the right between the folds of this side. It is not yet known whether or not it be by this opening that the ova escape after they have undergone incubation in the branchiæ, or whether they escape by the edges of these organs.

M. Prevost of Geneva has made some important observations on the generation of the Uniones, which appear to prove that although coitus cannot take place between the acephala, it is nevertheless necessary to their propagation that a certain number of these animals be found together near the same spot. From these experiments we may infer that a fecundating fluid is diffused in the water and absorbed by the ovary, which is thus fecundated without the contact of two individuals. This phenomenon is comparable to that which we know takes place in the fecundation of the ova of fishes; these are deposited by the female, and afterwards sprinkled by the male, who places himself above them, with the prolific fluid. Before adopting definitively the results of M. Prevost's experiments, however, it were necessary to repeat them a great number of times, in order to leave no doubts on this question, so interesting to the naturalist as well as to the physiologist, touching the generation of the hermaphrodite mollusca.

The number of eggs extruded by each individual is very great, and explains the rapidity with which these animals are propagated in certain seas, and the production by accumulated generations of those extensive beds of shells which are so frequently found covering the surface of actually existing continents.

Organs of motion.—The organs of motion are of two kinds: one is destined to move the two valves with which the animal is covered; the other is peculiar to a special organ, by means of which the animal moves its whole body. The muscles may therefore be arranged into two classes: 1st, adductor muscles of the valves; 2d, locomotory muscles, or muscles proper to certain organs. Those fleshy and fibrous fasciculi attached between the two shells, and which by their contraction approximate and close these two shells, are denominated the *adductor muscles*. In the greater number of the conchiferous mollusca, two of these muscles can be demonstrated, the one anterior (*c*, *fig.* 346; *h*, *fig.* 347; *a*, *fig.* 362) situated in front of the oral aperture, and the other posterior (*f*, *fig.* 346; *i*, *fig.* 347; *b*, *fig.* 362).

Lamarck has given the title of *Dimyaires* to all the mollusca having two adductor muscles, a character which he has invested with a considerable degree of importance, because it is constantly proclaimed by the interiors of shells, upon which the impression left by these muscles is very distinctly seen (*a*, *b*, *fig.* 367). One of these muscles, the anterior, diminishes gradually as we descend in the series of the Conchifera; in the family of Mytilacea it only exists in a rudimentary state (*a*, *fig.* 353); and after these it disappears entirely. In proportion as the anterior muscle disappears, the posterior one increases in size, and approaches more nearly to the middle of the valves. When no farther trace of anterior muscle can be discovered, the posterior muscle continues singly (*k*, *fig.* 348), and the mollusca having a single muscle, very distinct from the former which have two, have received the name of *Monomyaires* from M. Lamarck.

Poli, however, has shewn that the muscle of the Monomyaria consists in reality of two portions, readily separable from one another, and even differing considerably in their appearance. This leads us to presume, with every show of reason, that the single muscle in the Monomyaria is the result of the approximation of the two muscles, which are parted in the Dimyaria. This fact would incline us to regard the number of the muscles as a matter of but small importance in the classification of the conchiferous mollusks, and we may suppose that it was with such inductions before him that Cuvier was led to attach such slight significance to the division of these animals proposed by Lamarck.

The organ denominated *foot* in the acephalous mollusks is a part which presents very different forms, and is destined to locomotion. This part is particularly well developed among the Dimyaria, and we shall pass in rapid review its most general features.

The foot (*b*, *fig.* 346) is usually situated at the anterior and middle part of the abdominal mass, and is directed forwards. It is so placed as to hide the mouth in a deep sinus between its base and the anterior adductor muscle. In those conchiferous mollusks in which the lobes of the mantle are united through a great portion of their circumference, the foot is commonly very small and merely rudimentary; it then forms a kind of little nipple projecting from about the middle of the abdominal mass, a form which is very distinctly seen in the Mya, Saxicava, &c. In others of these mollusks the foot, more anteriorly situated, is extremely short, broadly truncated, and similar to a cupping-glass; this configuration is observed in the Pholadia. In proportion as the foot becomes more free, the lobes of the mantle are distinct from one another, the foot becomes flattened and elongated in the form of the human tongue, and is subservient to motion by digging a hole or furrow in the sand into which the animal sinks. This form of the locomotory organ is met with more especially in the Tellina, the Donata, and a very great number of other genera, the shells of which are more or less flattened. Lamarck had attached some consequence to the shape of the organ of locomotion, and Goldfuss has proposed a classification based upon the modifications presented by this organ; but the groups established in accordance with such considerations are in reality of no importance; the several forms proper to the organ pass too insensibly one into another to make it possible to say where one terminates and another begins; the boundary between one family and another, with a few rare exceptions, is altogether indefinite. In the present day, consequently, naturalists no longer admit into their methods of arrangement the groups established by Lamarck under the names of *Tenuipeda*, *Crassipeda*, &c.

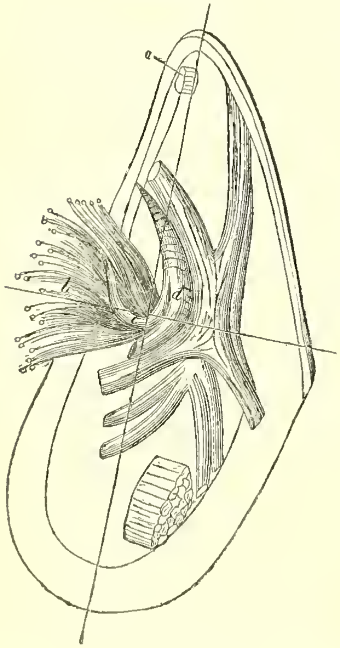
The foot exists developed in a greater or less degree in the whole of the Dimyaria. If in some species it is found merely rudimentary, it is yet never altogether wanting in any member of this first division of the Conchifera. The organ is also met with in a very considerable number, but by no means in the whole of the Monomyaria, and the presence or absence of the foot might be taken as the basis of a division of this great family into two series, in the one of which the foot was rudimentary but present, whilst in the other it was no longer to be found.

Whatever the form of the locomotory organ, and whatever the degree of its development, it is always organized in the same manner. It is essentially composed of several planes of muscular fibres (1, 2, 3, *fig.* 347), which by their various courses and interlacements enable it to perform a great variety of different motions, either in part or as a whole. When the foot is short or vermiform, its mass is entirely muscular from the apex to the base. It is at the base that the fleshy fibres separate into two fasciculi (4, 5, *fig.* 347), which, after having circumscribed the visceral mass, proceed backwards, where they are attached to each valve of the shell near the implantation of the posterior adductor muscle in the Dimyaria; and towards the superior part of the valves, and occasionally in the interior of the hook, or incurved part of the shell in the Monomyaria.

In the Conchifera denominated *Lamellipeds* and *Crassipeds* by Lamarck, in a word, in the whole of the Conchiferous mollusks in which the foot constitutes a principal part of the body, this organ presents remarkable differences in its composition and its relations with the internal organs. It is then formed of two lateral planes of fibres, uniting and blending together near the free edge. These two planes, more or less separate according to the general form of the animal, have between them an internal space, within which is included a considerable portion of the visceral mass. In the generality of conchiferous mollusks furnished with a large foot, it is here that a portion of the liver is situated, the greater part of the intestinal canal, and a notable portion of the ovary. These organs are bound down in the place they occupy, and the parietes of the foot are preserved in immediate communication by means of a great number of small muscles, sometimes straight, sometimes oblique, and variously interlaced, to which Poli has given the name of *funicular* muscles (*j, j, fig.* 347). They are particularly conspicuous in the cylindrical foot of the Solens, in the flattened foot of the Tellinæ, and of the Uniones, and they have a remarkable arrangement in that of the Cardiæ. They appear to be wanting in the foot of those Conchiferous mollusks that attach themselves by means of a byssus. In them the foot is reduced to the functions of spinning (*de filer*) the threads of the byssus, and it is not therefore surprising that its organization should be found to be peculiar. Reduced to a purely rudimentary state, the foot in the Monomyaria (*b, fig.* 348) appears rather as an appendage to the mass of the viscera than as their defensive envelope. The muscular fasciculi that terminate it posteriorly are small; they pass through the visceral mass to be attached either to the superior part of the central muscle, or within the interior of the hooks or beaks of the shell. Almost the whole of the Monomyaria furnished with a foot, have a byssus also; to this rule there are indeed a small number of exceptions, among others the Limæ.

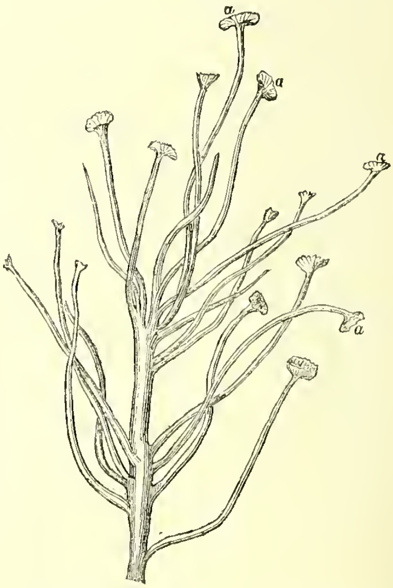
Up to the present time the faculty of producing a *byssus* is not known to belong to any other class of animals, and it is limited to a few only of the Conchiferous mollusks. Among the Dimyaria the genus Byssomya may be quoted as an example, also the members of the family of the Mytilacea; and, if the horny plates of certain Archæ be likened to the byssus, it would also be necessary to include this genus in the group of *byssiferous* Dimyaria. In the Monomyaria provided with a foot, the whole of the genera are byssiferous, with the exception of those which attach themselves immediately by their shell.

Fig. 353.



The *byssus* (*b, fig.* 353) is a bundle of horny or silky filaments, of different degrees of fineness and of different thicknesses, and flexible in various measures, by means of which the animal is, as it were, anchored to any solid body sunk in the sea. The filaments, for the most part distinct from one another, are, however, occasionally connected into a single mass of a subcylindrical form, and terminated by a broad expansion, which serves as the point of attachment. This disposition is to be observed in the Aviculæ, and leads to the belief that the horny mass of certain Archæ is a mere modification of the byssus. In those species of which a byssus is formed of separate filaments, these are all seen to be detached from a common pedicle (*c, fig.* 353), situated at the inferior base of the foot (*d, fig.* 353). If the byssus be examined before any of the filaments are torn, it is easy to perceive that these are attached to submarine bodies by means of a small disc-like expansion of their extremities, of various extent according to the genus and species (*a, a, a, fig.* 354). Attentive examination of these filaments shews that they are of equal thickness through their entire length, and that they have nothing of the structure of the hair of the higher animals.

Fig. 354.



If the byssus and foot of a byssiferous mollusk be placed under a powerful lens, the last filaments of the byssus are first seen to be nearest to the base of the foot; and if the inferior edge of the foot be inspected, a fissure will be found running completely along it, at the bottom of which a brownish and semi-corneous filament is often to be perceived; this is neither more nor less than a filament of the byssus prepared to be detached by the animal, in order to which the animal stretches forth its foot until it encounters the object upon which the other fibres of the byssus are fixed; to this it applies the point of the foot, which then secretes a small quantity of glutinous matter, continuous with the silky filament lying along the bottom of the furrow of which we have spoken. When the pasty matter has acquired sufficient consistency, and is firmly fixed to the stone or other body at the bottom, the animal retracts its foot, and in doing so detaches the new fibre to the base of the pedicle. The mode in which the filaments of the byssus are formed, is consequently entirely different from that in which hair or the horns of the higher animals are evolved, and it is easily understood when the intimate structure of the foot of the byssiferous mollusks is known, when we are aware that this organ consists in its centre of a pretty considerable fasciculus of parallel and longitudinal fibres. By a faculty peculiar to the class of animals that now engages our attention, the fibres situated at the bottom of the groove of the foot become horny, and are detached in successiou in the form of threads as they become consolidated. Certain genera are celebrated for the abundance and fineness of the byssus; that of the Pinnæ, among others, which was even known to the ancients, may be spun into threads like silk or wool, and may be used to manufacture tissues of an unchangeable colour, and of great strength and durability.

With reference to *form*, the foot presents a variety of interesting modifications. Sometimes it is short and truncated, as in the genus *Pholas;* sometimes more elongated, but still truncated at the summit, as in certain Razor-shells *(Solen)*, (*a*, *fig*. 355); in which the edges of the truncation are regularly toothed. A few of the acephalous mollusks have the foot cylindrical (*a*, *fig*. 356), as the *Solenes;* when it presents this form, the organ is generally terminated by a kind of glutinous point, or disc, which enables the animal to fix itself at different heights in the deep cylindrical hole it digs for itself in the sand. The foot, which is shaped like a tongue, is named *linguiform*, as in the *Solen strigilatus;* it is *claviform* when it is thicker at its extremity than at its base: it is found of this shape in certain other Solens. The foot again is *vermiform* when it is very slender and much elongated, as in the *Loripes* and *Lima*. When it is thus formed, it appears to us to be incapable of subserving motion. In a considerable number of species the foot is conical, as in the Cockle, (*a*, *fig*. 357); and in this case it is generally folded into two nearly equal portions, so that by its means

Fig. 355.

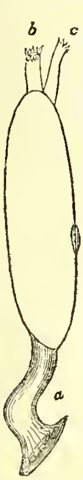


Fig. 356.

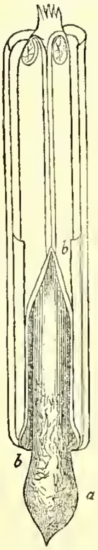
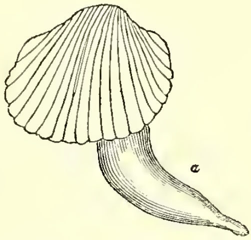
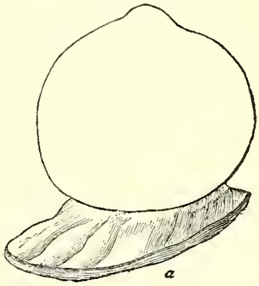


Fig. 357.



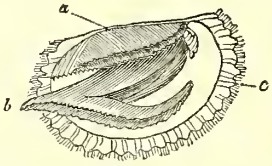
the animal can leap pretty actively. It is *securiform* when its free edge is arched like the cutting face of an axe, as in *Petunculus*, (*a*, *fig*. 358). When it presents this form its edge

Fig. 358.



is generally divided into two lips, which, being separated, present with some degree of accuracy, although much contracted, the semblance of the locomotive plane of certain Gasteropoda. When this structure occurs, the

Fig. 359.



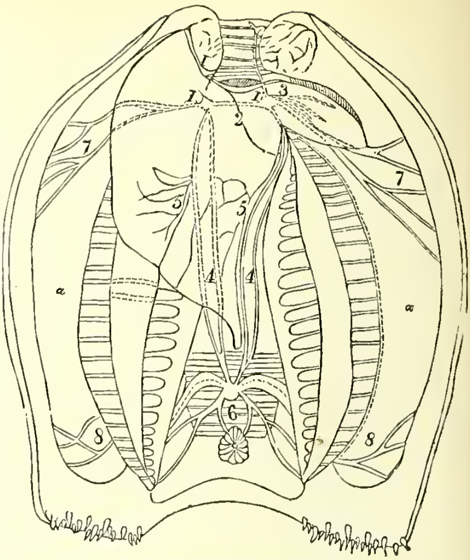
foot is said to be *bifid*, as in *Nucula*, *Trigonia*. It is said to be *flattened* when it is thin and laterally depressed, as in *Tellina* and *Donax;* to conclude, it is designated as *bent* when it consists of two portions connected at an angle with one another (*b*, *fig*. 359), of which the genera *Cardium*, *Nucula*, and *Trigonia* present examples. Various other modifications, of less importance than those we have particularized, also occur; these can be aptly enough alluded to in the anatomical description.

From what has now been said it is easy to understand the offices performed by the foot. In the lithophagous and xilophagous Conchifera, the foot, reduced to its rudimentary condition, is probably without any particular use, unless perhaps it be among the Pholades, where, being in the form of a sucker, it may enable the animal to fix itself to the parietes of the cavity it inhabits. Among the Conchiferous mollusks that live at large, the chief use of the foot is to dig a furrow, into which the animal forces itself partially, and then advances slowly by making slight see-saw or balancing motions, a circumstance which has led Poli to designate the whole class of acephala by the title of *Mollusca subsilentia*. Several of these Mollusks not only make use of the foot in the way we have just mentioned, but also employ it as a means of executing sudden and rapid motions, true leaps, by which they are enabled to change their place with great celerity. It is of course unnecessary to say that in those genera whose shell is attached immediately to the bodies at the bottom of the sea (Chama), the foot is of no use as an organ of locomotion at all events. In the byssiferous species, again, the organ, although but slightly developed, is the agent in spinning the filaments of this cable.

Nervous system.—Anatomists were long ignorant of the existence of a nervous system in the Conchiferous mollusca. Poli first discovered it in the course of his dissections, whilst preparing subjects for the plates of his magnificent work, entitled, *Testacea Utriusque Siciliæ;* but he mistook the nervous system, occasionally of considerable magnitude, for one of absorbent or lymphatic vessels, and spoke of it under the name of *lacteal* vessels. In a very interesting memoir, Mangili exposed the error which Poli had committed, and rectified it by assigning to the *vasa lactea* of his learned countryman their true place as portions of the nervous system.

The acephala have no brain properly so called. The nervous system is symmetrical in the Dimyaria, but loses this character in some measure in the Monomyaria. This diversity in the nervous system, coinciding with the number of the muscles, gives a higher value to the character which is established on the existence of one or two adductor muscles. In the Dimyaria we find, on each side of the mouth, a small ganglion above the œsophagus, towards the base of the labial palps (1, 1, *fig.* 360). Each of these ganglions is of an oval or sub-quadrangular shape, and the two are connected by means of a transverse filament (2, *fig.* 360) running across or over the œsophagus. From the edges of the ganglions many filaments arise, some of which on the sides descend into the substance of the labial palps (3, *fig.* 360); others anterior are distributed to the edges of the mouth; and others run to the lateral parts of the anterior adductor muscle, gain the thick portion of the edge of

Fig. 360.



Nervous system of an Unio.

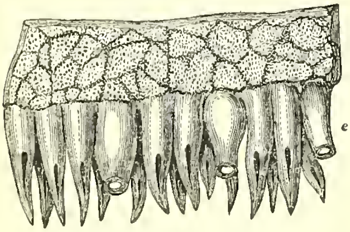
the mantle, and detach numerous branches. From the posterior edges of these anterior ganglions there is one, and occasionally there are two nervous branches of considerable size sent off (4, 4, *fig.* 360); these descend along the body towards the base of the branchiæ, concealed amidst the visceral mass, and give off filaments in their course to the neighbouring organs, first to the stomach, then to the liver and heart, and next to the ovary and branchiæ. A considerable branch descends on each side of the foot, and is expended upon this organ. When the lateral filaments have arrived opposite to the posterior adductor muscle, they advance along its internal surface, approach one another, and at their point of junction give origin to one or two ganglions of different sizes, but always larger than the anterior ganglions. When the posterior ganglions are some way apart, a nervous filament always connects them. It is from these posterior ganglions that the nervous cords are detached, the branches of which are distributed to the whole posterior parts of the animal. Some run towards the anus, others to the thin portion of the mantle, and a considerable number to the thickened margin of the same organ. When the lobes of the mantle are conjoined posteriorly, and are continued from this part by means of siphons, among the nervous branches which follow the thickened edge of the mantle, one is distinguished of larger size than the others, which terminates at the point of commissure in a small ganglion. This little ganglion is not met with in the Dimyaria without a siphon; neither does it appear in the Monomyaria. When the siphons occur, however, a retractor muscle, peculiar to them, is almost invariably found also, as we have already seen. When these two parts exist, nervous branches are likewise discovered, destined for them, one for each of the retractor muscles, and one for each of the siphons. The posterior part of the nervous system of the Dimyaria is so considerable in comparison with the anterior part, that some anatomists have maintained that the title of brain should be given to the posterior ganglions, conceiving them to be of much greater consequence in the organization of these animals, and of more avail in regulating their functions than the anterior ones.

In the Monomyaria the nervous system is in general less perfectly developed than in the Dimyaria. It is not quite symmetrical, and the posterior are not larger than the anterior ganglions. The nervous cords, too, are much more slender, and not nearly so easy of demonstration as in the Dimyaria; it was not without difficulty that we discovered them in the common Oyster, the Pecten and the Spondylus. Poli has said nothing upon the nervous system of these genera. Our own researches in quest of it were perfectly fruitless at first; but having bethought us that in the Dimyaria the nervous cords of the labial palps were always to be discovered without difficulty, we sought for the same filaments in the Monomyaria, and were lucky enough to find them; these led us by-and-bye to the anterior ganglions, and by degrees to the detection of the entire nervous system. The anterior ganglions in the Monomyaria are extremely small; they send a principal filament to each of the palps; a cord proceeds from them to the anterior part of the mantle which covers the mouth; another runs from the ganglion of one side to that of the other, passing above the œsophagus; and from the posterior angle several branches are detached to the liver, the stomach, and the branchiæ. Among these there is one, and sometimes two, which, resting on the internal aspect of the central muscle, bend obliquely over its surface, and finally unite occasionally to form a small posterior ganglion. This ganglion sends branches to the heart, to the ovary, and to the posterior parts of the mantle. The parallel cords traverse the thin part of the mantle, sometimes radiating in a slight degree, and divide into numerous branches within its thick margin and the tentacular ciliary processes that fringe it. There is one among the monomyary genera, the nervous system of which we have not been able to study with due attention; this is the genus Lima. From what we have seen of it, however, it would appear that the nervous system in this genus is every way as perfectly symmetrical as in the Dimyaria. But before admitting this as a fact definitively, it were necessary to have verified its accuracy at least several times, which we have as yet had no opportunity of doing.

When we consider the great simplicity of the nervous system of the acephalous mollusca, we can only conceive these animals endowed with sensibilities extremely obscure, and with instincts extremely limited. No especial organ of sense can be detected among them, unless perhaps it be that of touch, which appears to reside in every part of the body and of the mantle, and probably also the sense of taste, of which in all likelihood the maxillary palps are the organ. The manner of existence of these animals is in perfect accordance with the great simplicity of their nervous system. Many genera live attached to submarine objects, either by the shell immediately or by means of a byssus, taking no pains to avoid or to protect themselves from danger, and giving no sign of existence but by opening and shutting their shells: they shut them when any foreign body comes in contact with their mantle; and they open them to admit the water which brings suspended in it the nutritious particles which they seize upon for their subsistence, and which is in itself necessary for the purposes of respiration. Among the acephalous mollusca which are not fixed in the manner of those now mentioned, those which have no siphon, or which have this part very short, live at the bottom of the sea, in spots covered with sand or mud, amidst which they burrow by means of the foot, and support themselves in an oblique position by resting upon the half-open valves of their shell. The acephalous mollusca again, which are furnished with a siphon, almost all bury themselves more or less deeply amid the sand or the mud of the bottom, contenting themselves with an ascending or a descending motion, the latter sufficient in the moment of danger to gain the limits of their retreat, the former to enable them to protrude the free extremity of their siphon when they would establish the current of water necessary to their nutrition and respiration. It is easy to imagine that among animals whose functions of external relation are so limited, the nervous system must continue extremely simple, a fact which could in some measure be predicated from observation of the habits of the extensive class whose structure and economy we are now engaged in considering.

Of the skin and its appendages.—The mantle.—The acephalous mollusca are enveloped by two very thin fleshy laminæ, which are seen covering or closely applied to the whole of the inner surface of the shell; this is the part to which the name of mantle has been given (*c*, *fig*. 359; *a*, *a*, *fig*. 360). This name has been very appropriately given to this cutaneous envelope, for it appears to be applied over the back of the animal, and to be extended over the lateral parts, to meet by its edges along the anterior middle aspect of the body. The mantle is composed of two parts generally equal, or nearly equal, each of which has been designated one of its lobes. In the natural position of the animal, one of these lobes is in relation with its right side, the other in relation with its left side; they adhere intimately to the superior and posterior part of the body; they become free at the origin of the branchiæ, and form around the whole inferior part of the animal a cavity of various dimensions, within which the abdominal mass, the foot, and the branchiæ are included. It is in this palleal sac that the animal establishes a current of water, destined to minister to the function of respiration, and to carry towards the mouth the alimentary particles with which it is fed. The median parts of the lobes of the mantle are extremely thin and transparent, and a great number of vessels (*c*, *fig*. 362), and a few nervous filaments (7, 8, *fig*. 360) are perceived ramifying through their substance, and running towards the anterior and inferior edges. These edges, which extend as far as those of the shell, are thickened, and it is at the point where the thickening begins that the mantle adheres to the shell by means of a great number of minute muscles (*l*, *l*, *fig*. 347; *d*, *fig*. 362), which leave a linear impression upon it. The thickening of the edges of the mantle is owing to the presence of a great quantity of muscular fibres, frequently to several rows of contractile tentacular cilia (*m*, *m*, *fig*. 347; *e*, *fig*. 361 & 362); and, lastly, to that of an organ, which is the secerning apparatus of the shell. The muscular fibres are

Fig. 361.



Contractile cilia magnified.

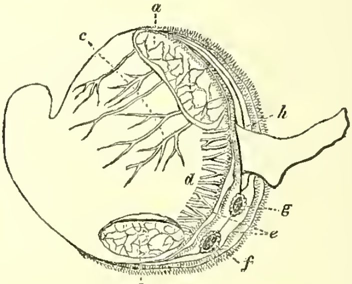
distributed some to the edges of the mantle, and others to the tentacula with which it is fringed. The whole of these parts are extremely retractile, and are endowed with such sensibility that the slightest contact is perceived, as is evinced by their instantaneous contraction.

Zoologists have taken advantage of certain modifications in the lobes of the mantle to establish divisions in their methodical arrangements of the conchifera. This artificial means is sufficiently convenient, inasmuch as no anatomical inquiries are necessary in order to get at the distinguishing characters which these modifications supply. Latreille, in his 'Familles du Règne Animal,' as well as other zoologists, have also made use of the conjunction or disunion of the lobes of the mantle to establish the principal divisions of their classification; but they have perhaps given too much consequence to these characters, inasmuch as they bear no relation to the number of the muscles. Nevertheless, none of the Monomyaria has yet been found which presents the lobes of the mantle conjoined, whilst the Dimyaria exhibit the two modifications which we have had occasion to mention, and which gives an opportunity to divide them into two grand series, the first comprising the whole of the Dimyaria whose mantles are united, the second all those whose mantles are open, or unconnected one lobe with another. The conchiferous Dimyaria which exhibit the lobes of the mantle united are modified in this respect in a remarkable manner, a circumstance which induces us to enter somewhat in detail into this part of the anatomy of the conchifera.

In making the series of acephalous mollusca commence with those which have the lobes of the mantle completely distinct, we may place near them certain genera in which the branchiæ, conjoined in their posterior parts, form a kind of canal, within which the anus proceeds to terminate. This conjunction of the branchiæ, extending as far as the edge of the mantle, forms a kind of band towards the posterior commissure; but, notwithstanding this, it may still be said that these animals have the lobes of the mantle altogether unconnected (Unio) (*fig*. 360); in other genera which have been held allied to this, the posterior band is not found, and already the lobes of the mantle appear united in the posterior part, to a very small extent, leaving a particular perforation for the anus. The mantle still continues open in its circumference (Mytilus). By-and-by neighbouring genera, and even particular species of the same genus, instead of a single perforation, present two (*f*, *g*, *fig*. 362); the second is destined to carry the water directly upon the branchiæ. When these two perforations have the faculty of being projected beyond the shell in the form of fleshy and contractile tubes of various lengths, they have received the special denomination of *siphons;* and the term *perforation* has been reserved to be applied to the holes of the mantle, which never pass the edges of the shell.

When the two siphons begin to appear, the lobes of the mantle still continue disjoined in a portion of their circumference; and this opening (*b*, *b*, *fig*. 356, *h*, *fig*. 362), is destined for the passage of the foot.

Fig. 362.



In proportion as the foot is modified in its form, in proportion as it becomes more rudimentary, the two lobes of the mantle are observed in the succession of genera to become more and more extensively united, and it happens at length that in certain genera (Mya, Saxicava, &c.) a very minute submedian or anterior perforation, corresponding to the rudimentary foot, is all that remains of separation between them. It is a circumstance worthy of remark that the siphons are observed to become elongated and thickened in proportion as the lobes of the mantle are more extensively united. This circumstance, however, is only true in a general way, for it would be easy to quote many striking exceptions to it.

2. *Siphons.*—We have already had occasion to see the siphons commence in certain genera by simple perforations; they increase in length in the succession of genera; and in a certain number they always continue unconnected through their entire extent (*g, h, fig.* 346; *b, c, fig.* 355). In other genera, however, the siphons are seen at first united towards their base, then conjoined nearly to the middle, cohering almost to their ends, and finally blended through their whole length, so as to form a single elongated subcylindrical fleshy mass, pierced through its entire length by the canals of the two siphons, one of smaller size, situated superiorly for the anus, the other larger, situated under the former, and destined to transmit the water to the branchiæ. Whether connected or not, the superior siphon is always characterized as the *anal*, the inferior as the *branchial* siphon.

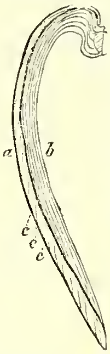
The structure of the siphons is entirely muscular, so that their free extremities are capable of contracting and of being elongated to a very considerable degree. They are beset around their external orifices with a great number of papillæ, (*n, o, fig.* 347), occasionally truncated at their extremities and of exquisite sensibility. The water has to pass over these papillæ before it can enter the mantle, and undoubtedly they apprise the animal of the presence of every foreign body that might injure it. In a few genera the siphons contract by means of their component muscular fibres; but in the greater number they have a particular retractor muscle running on each side of the animal, and in relation, in point of magnitude, &c. with the length and degree of contractility possessed by the siphons (*p, fig.* 347). The existence of this muscle, and consequently of siphons, is manifested on the interior of the shell by a posterior sinuous furrow of various depth, and indicating upon a narrow line the point of implantation of the retractor muscle of the siphons.

In some of the acephalous mollusks the siphons are too large to be received within cover of the shell, in which case the retractor muscle is generally small, inasmuch as it is then of little use (Mya, Glycimeris); but in those species in which the siphons are of middling size, or not so large as to be incapable of entering the shell, the retractile muscle is of considerable size and power (Tellina, Psammobia).

3. *The shell.*—The lobes of the mantle appear to be the efficient parts in determining the form of the shell, and it is by their thick edges that this covering is in great part secreted. The whole of the Conchiferous acephala, without exception, are included within a bivalve shell, the two parts of which are joined by a point in their upper edge, to which the title of *hinge* has been given by naturalists, and very properly, because it is in truth upon it that the motions of the valves take place.

General structure.—When examined with due attention, the shell is found to be composed of two kinds of laminæ very distinct from one another (*a, b, fig.* 363); the one, secreted from within outwards by the edges of the mantle, present themselves under the form of greatly elongated cones, the thick parts of which are turned towards the outer surface (*a, c, c, fig.* 363); the other, in parallel layers, secreted by the central and posterior parts of the mantle, line the interior of the shell, and in many species at length fill up the cavity of the hooks. These two layers of the shell are frequently found in certain fossil species almost completely separated from one another. At other times the inner layer is seen to have been dissolved away, whilst the external one continues without appearing to have undergone any great change. It is in the genera *Chama, Mytilus, Pinna, Spondylus,* more especially that the two laminæ of which a bivalve shell is formed can be studied to greatest advantage, and this study is of importance as leading to a more accurate knowledge of certain fossil genera, in regard to the character of which some uncertainty has always prevailed, by reason of one of the constituent portions of their shell always being found dissolved, as in *Patillus.* In some genera the external layer is very readily distinguished, from having a fibrous structure (*a, a, fig.* 369), a structure observed more especially in the shells of the *Pinna* family and those of the *Malleacea.* The two layers of the shell are in the inverse ratio of one another in point of thickness: the external layer, extremely thin towards the hook, increases continually towards the edges, whilst the inner layer, thick at the hook, becomes thinner and thinner as it approaches the edges, around which it is usually exceeded a little by the outer layer. A fact well deserving of attention is this:—that the muscular impressions and the whole articular aspect of the hinge are formed in the substance of the inner layer of the shell, and these parts, of so much consequence, do not leave a trace upon the external layer when this alone is preserved. It is only from having neglected to study the structure of the shell with sufficient attention that naturalists have found themselves at a loss to discover the true characters of certain fossil genera, as *Podopsis, Spherulites,* which, in consequence of their position in porous chalky beds, never occur with more than the outer layer of their shell in a good state of preservation.

Fig. 363.



The hinge.—The part of the edge of a shell by which the two valves are conjoined, is, as we have already had occasion to state, denominated the *hinge.* This part is entirely formed by the inner layer of the shell. The part of the shell, of various length and thickness, upon which the hinge occurs, is called its *cardinal edge*. In the hinge two structures are apparent: 1st, an elastic ligament, the position of which is variable; 2d, projections and corresponding cavities on either valve, destined undoubtedly to give additional strength to their union.

1. *The ligament.*—The ligaments of bivalve shells are distinguished into two kinds, according to their structure and their position: they are *internal* when they are completely hidden by the cardinal edge of the shell; they are *external* when they appear on the outside beyond this edge. The internal ligament is composed of a great number of highly elastic fibres, parallel to one another, and perpendicular to the valves they connect. They are secreted by a lamina of the mantle, projecting upon the back of the animal, and penetrating between the edges of the two shells. The fibres of the ligament secreted when the shell is partially open, are of too great length when it is shut, so that when the valves are approximated to one another these fibres are forcibly compressed, and their elasticity is brought into play, by which it is only necessary for the animal to relax its adductor muscles in order to have the fibres of the ligament, in their effort to regain their natural length, force the valves apart from one another to a determinate extent. When the ligament is external, it rests upon the prominent parts of the cardinal edge, parts to which the title of *nymphæ* has been given (*a, a, fig.* 365). When the ligament is of this kind, it consists of two distinct layers, one external, thin, and very strong, composed of transverse fibres, which extend from one nympha to the other, and are strongly inserted within a groove hollowed out of the base of each of them. The other portion of the external ligament is of precisely the same structure as that of internal ligiments, and is comprised between the nymphæ and the outer layer, of which we have just made mention. The action of this ligament is also precisely the same: it forces the valves apart when the animal ceases to maintain its adductor muscles in a state of contraction.

In the extensive series of Conchiferous mollusks, some modifications, as might have been anticipated, are met with in the conformation of the ligament, external as well as internal. If many members of the family of the Dimyaria be examined, the ligament, very prominent outwards, will be seen bearing upon nymphæ more prominent externally than the cardinal edges, but contracting gradually under this edge in proportion as the nymphæ become shorter, until in some species we find that, still preserving the structure of the external ligament, the whole of this apparatus is nevertheless entirely hidden under the superior edge of the shell. This point attained, the external ligament alters by insensible degrees into a ligament completely internal; that is to say, the exterior fibrous layer diminishes gradually, and at length disappears entirely when the ligament is much developed upon certain internal parts of the hinge. Our own opinion is, that the ligament is internal when the nymphæ, having undergone certain modifications, have been transferred to the interior, and have assumed the form of acetabula. The ligament is sub-internal when the nymphæ, of less depth, still show a portion of the ligament externally; finally the ligament is external when the nymphæ are situated towards the upper edge of the shell. This displacement of the ligament, and of the solid part which gives it insertion, is very well seen in the succession of the following genera: *Solen, Panopus, Thracia, Calcinella, Amphidesma, Lutraria, Mactra, Mya, Crassatella.*

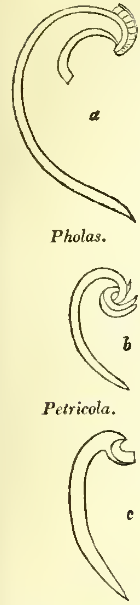
In those shells in which the beaks or hooks are of great size, and spirally turned to one side, the ligament, in keeping pace with the growth of the covering, bifurcates at its anterior part, and this bifurcated part then becomes useless. This circumstance is particularly remarked in the Isocardium and the Chama. The ligament also presents a very remarkable peculiarity in the three genera of the *Arca* family. The superior surface of the hooks in these genera (*Arca, Pectunculas, Cacullæa*) is of greater or less breadth, flattened, triangular, sometimes furrowed, and has a thin ligament, resembling an elastic web, strongly attached to it.

The ligament in the greater number of the genera of the Monomyaria is situated within a triangular groove or depression of a breadth corresponding to its dimensions. In one family, that, namely, of the Malleacea of Lamarck, several genera (*Perna, Crenatula*), instead of having a single ligament, have a regular series of fossiculæ, in each of which a ligament is implanted.

Cardinal edge.—The cardinal edge presents a great number of modifications. Sometimes it is simple, and of various degrees of thickness, in which case the hinge is said *not to be articulated;* sometimes it presents projections and reciprocal cavities, in which case the hinge is said *to be toothed* or *articulated* upon the cardinal edge. These projections and hollows are remarkably regular in their formation, and every change in their appearance commonly coincides with one of greater moment in the organization of the animal. This remarkable coincidence, to which only a very few exceptions are yet known, has led conchologists to attach great value to the characters derivable from the hinge, and Lamarck, among others, has grouped several families and a great number of genera after them. We believe, with this celebrated naturalist, that the hinge supplies excellent characters for the distinction both of families and genera, but we have been led to this conclusion by viewing the subject in a different point of view from that taken by Lamarck.

Every conchologist knows the interesting genus denominated *Pholas.* In the interior of the valves of this genus there always exist two kinds of large curved processes, extending from the interior summit of the hooks (*a, fig.* 364), and advancing nearly to the middle of the valves. According to our views

Fig. 364.

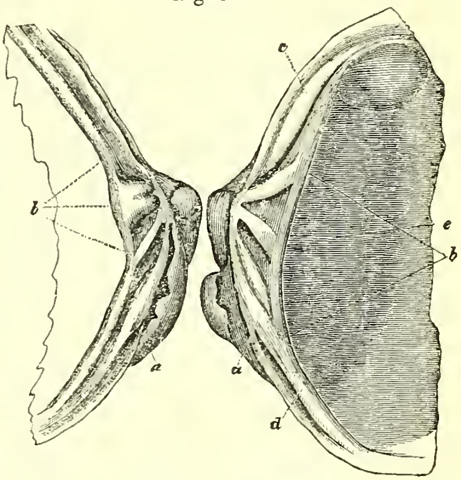


Pholas. *Petricola.*

these appendages are the first parts of the cardinal teeth. There is one fact which deserves to be insisted on in connexion with this genus; it is that there are no ligaments found, and that the cardinal edge, folded in upon itself *(rentré sur lui-même)*, is not flattened and placed in the same manner as in the other conchifera. Another circumstance of equal importance to be mentioned is that the processes, of which we have just spoken, are buried in the substance of the animal, and covered with a duplicature of the mantle which accompanies them as they plunge amid the visceral mass. Without leaving the genus Pholas, the cuillerons may be seen gradually contracting in their breadths, becoming shorter, and approaching nearer and nearer to the edge. But if other shells be examined, which obviously form the links of transition from the *Pholada* to the *Saxicava*, or *Petricola*, the processes are found to turn upon the edge, to become coherent with it so as to form a salient margin, and by their free extremity to produce a projection (*b*, *fig.* 364). In our opinion the toothings of the hinge of all the other bivalve shells are produced in the same manner; but with such modifications as rarely admit of those relations being traced which are to our mind obvious in those genera that have just been particularly mentioned. With regard to the shells of the genera in which the hinge is complicated, of which the cardinal edge is thickened, and the cavity of the hook partly filled by the external layer of the shell, it is difficult to imagine in what manner the successive growth of the hinge has taken place, and to make out its analogy in point of structure with that of the *Petricola pholadiformis* and of the *Pholada* generally. To discover this it is necessary to break a great number of the shells, or to make various sections of the edge, when the direction of the denticulations with which it is furnished must be followed. The teeth of the hinge will then be seen arising from the summit of the hook (*c*, *fig.* 364), becoming developed, and forming a solid arc, surrounded and hidden by the matter of the cardinal edge itself, and these arcs thus disengaged will be found to present the strongest analogy with those of the Pholada. It is from viewing the hinge in this manner that we have been induced to think that its structure was in reality of sufficient importance to make it be constantly appealed to for the distinguishing characters of genera.

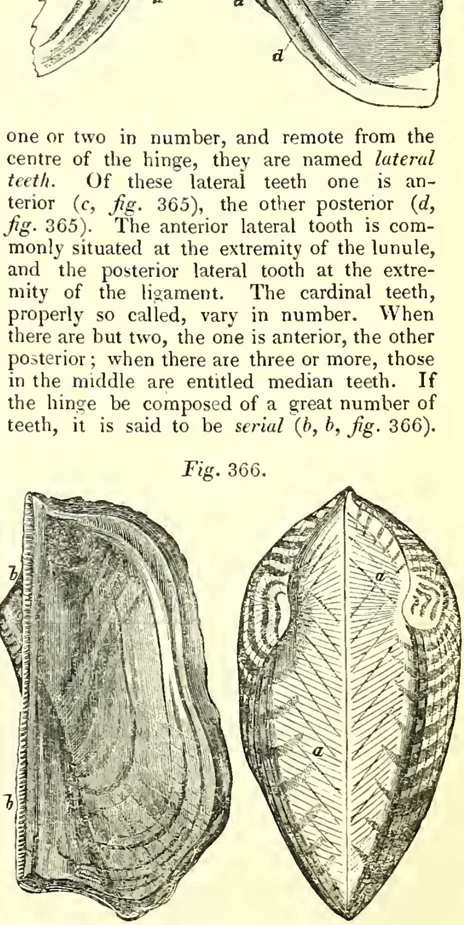
Naturalists have agreed to designate as *the cardinal teeth* those solid projections which arise on the edge of the hinge. These projections on the one valve are for the most part accompanied with corresponding depressions on the other for their reception mutually. The depressions are called cardinal pits. These cavities and these projections present a great variety of modifications which cannot be well understood without a long and careful study of the conchiferous tribes generally. When the teeth are collected under the hook, they preserve the title of *cardinal* (*b*, *fig.* 365); when

Fig. 365.



one or two in number, and remote from the centre of the hinge, they are named *lateral teeth*. Of these lateral teeth one is anterior (*c*, *fig.* 365), the other posterior (*d*, *fig.* 365). The anterior lateral tooth is commonly situated at the extremity of the lunule, and the posterior lateral tooth at the extremity of the ligament. The cardinal teeth, properly so called, vary in number. When there are but two, the one is anterior, the other posterior; when there are three or more, those in the middle are entitled median teeth. If the hinge be composed of a great number of teeth, it is said to be *serial* (*b*, *b*, *fig.* 366).

Fig. 366.

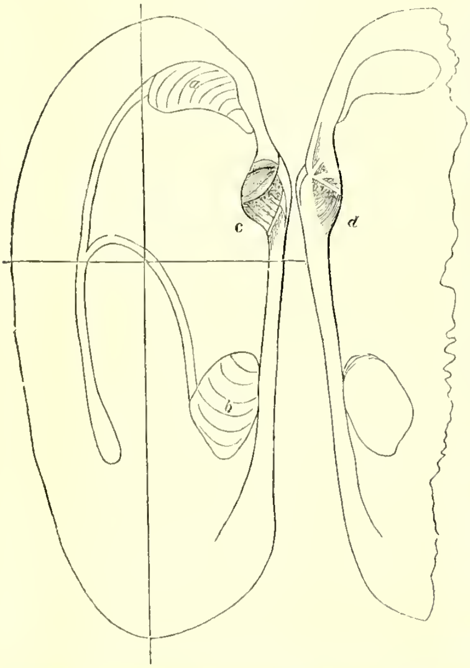


Arca.

The teeth are commonly simple and conical; occasionally they are flattened either lengthwise or transversely. In a considerable number of species they are grooved to different depths on their summits, and the teeth are then said to be bifid (*c*, *fig*. 365).

There are other parts still which present themselves upon the cardinal edge, and of which it is important to have a sufficient knowledge,—namely, those destined for the implantation of the ligament when it is external; to these parts the name of *nymphæ* is given. These form two callosities more or less prominent, which are seen along the posterior and superior edge of the shell. When the ligament is internal, it rests upon a cavity generally prominent towards the interior of the valves, and designated by the name of *cuilleron* or spoon-shaped cavity. This *cuilleron* is generally situated in the centre (*c*, *d*, *fig*. 367) of the

Fig. 367.



hinge; sometimes, however, it becomes a little oblique, elongated, narrower, and runs in the direction of the posterior and superior edge.

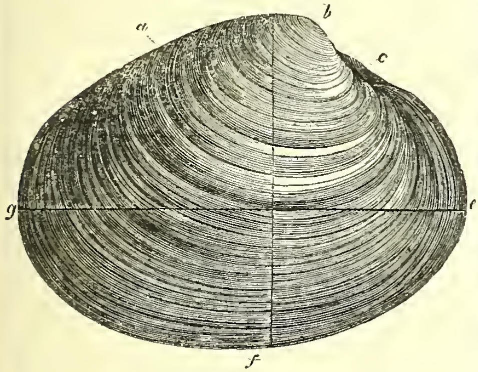
When we direct our attention to the external forms of the bivalve shells, we observe numerous modifications, of the principal of which it is necessary to take some notice. In a considerable number of species the two valves are alike, when the shell is said to be *equivalved*. When one of the valves is larger than the other it is of course *inequivalved;* to constitute it so it is not necessary that the shell should be *irregular*. A *regular* shell is that which at liberty always presents the valves alike in all the individuals of the species; an *irregular* shell is not only inequivalved, but farther, the whole of the individuals of the same species are not exactly of the same form, and want the same peculiarities of external conformation generally. The Oysters are inequivalve and irregular shells; the Corbules are inequivalve and regular shells; the Venus and many others are perfectly equivalved and regular; the Placunes, to choose a particular example, are in like manner equivalved but irregular. The length of a shell is always calculated from the summit of the hooks to the inferior edge. All that are of greater length than breadth are entitled *longitudinal*, (*Mytilus*, *Pinna*, &c. *fig*. 353); and all that are of greater breadth than length are named *transversal:* the breadth is estimated by a line passing from the anterior to the posterior extremity, and cutting the posterior axis of the shell at a right angle, (*Solen*, *Tellina*, &c. The number of transverse bivalve shells is very great: *fig*. 367). If the position of the hooks with relation to the transverse and longitudinal lines be considered, the shell is said to be symmetrical, when, the hooks being in opposition, the anterior segment is equal to the posterior, and of the same form in consequence of this symmetry; a perfectly symmetrical bivalve shell might in fact be held to be composed of four similar parts; but this perfection of symmetry, which exists in many Brachiopods, never appears among the conchifera properly so called, even those which are the most symmetrical in external character, as certain *Petuncula*, *fig*. 358, would be more correctly designated as *sub-symmetrical*. When the hooks are inclined to one side of the shell, and divide it into two equal parts, it is said to be *equilateral*. But if the hook be carried further forwards than backwards, so that one of the sides of the shell then becomes larger than the other, it is said to be *inequilateral*. In the greater number of the conchifera the two valves of which the shell consists join each other accurately around their whole circumference, in which case the shell is said to be *shut* or *closed*. When, on the contrary, the two valves present a vacancy between them in some part of their circumference, when they are approximated as nearly as possible to one another, the shell is said to be *patulous*. This open space is variously situated in different species, sometimes in the anterior surface, rarely in the inferior edge, but pretty frequently in the posterior edge, especially in those species of the class whose mantle is prolonged on this side into one or two syphons.

Surfaces of the valves.—Every bivalve shell has two surfaces, an external surface and an internal surface. Various parts are distinguished on the external surface,—the hooks, the belly, the edges, the lunule, and the corslet.

External surface. 1. *The hooks*. — The protuberant opposed parts, often inclined towards the anterior side, and presenting an apex of various degrees of sharpness or bluntness, are thus denominated. When these hooks are very much inclined forwards, they are styled *lateral*. If they are particularly prominent, they are said to be *cordiform.* When they are inclined towards one another, so that their summits approximate, they are said to be *opposed*. The hooks in no case incline to the posterior side; but occasionally they disappear almost entirely, and, as in the Solens, exhibit no kind of prominence. In other instances again they project a great way, and form the most prominent part of the shell (Mytilus, Pinna), in which case the hooks are said to be *terminal.*

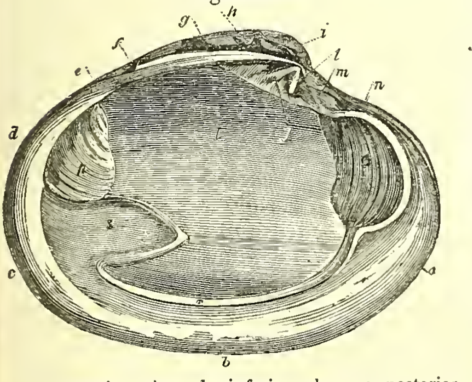
2. The *belly* of the shell comprises the greatest part of the exterior surface. It is bounded at the base of the hook, as also by the lunule and the corslet. It is more or less rounded or flattened according to the general form of the shell, and we shall speak of the different points worthy of consideration connected with it when we come to define the various particulars of the external surface considered in a general manner.

Fig. 368 A.



a, superior edge; *b*, uncus; *c*, lunula; *e*, anterior edge; *f*, inferior edge; *g*, posterior edge.

Fig. 368 B.



a, anterior edge; *b*, inferior edge; *c*, posterior edge; *d*, edges of the shield; *f*, ligament; *f* to *h*, nympha; *h*, other extremity of the ligament; *i*, point of the uncus or hook; *l* to *n*, lunula; *l*, anterior cardinal tooth; *j*, median cardinal tooth; *g*, posterior cardinal tooth; *m*, anterior lateral tooth; *o*, anterior muscular impression; *p*, posterior muscular impression; *r*, palleal impression; *s*, sinuosity of the palleal impression.

3. *The edges.* — These are indicated, preserving the shell in the position which we have mentioned; they are anterior, posterior, inferior, and superior. The extent of these edges is very various, and depends entirely on the form of the shell and the position of its hooks. Upon this particular the simple inspection of a collection of shells will give much more information than we can hope to do by the most laboured description; so that we shall only say that the anterior edge corresponds to the head of the animal, the posterior to its posterior extremity, the inferior to its ventral aspect, and the superior to its back. The edges in themselves, however, present a few particulars which it were well to mention. Sometimes they are thin and cutting; very commonly too they are thick and continue simple. In those species especially whose shells are marked externally with longitudinal striæ, they are notched and toothed alternately, the projections of the one valve in almost all instances being received into the cavities of the other. When these projections and notches are very fine, the shell is said to be *crenate;* if larger, *toothed;* when very large and few in number, with their summits blunt, again, the edge is *undulating* as in the Tridacna; on the contrary it is *angular* when the prominences continue sharp as they do in certain of the Ostreæ; in the latter case the edge is also said to be *widely* or *deeply dentated.*

4. The *lunula* does not occur in every genus of bivalve shell. It is met with, however, among the greater number of the Monomyaria; it is also met with among many Dymyaria, and is particularly conspicuous in the *Venus.* It is a space comprised on the anterior surface immediately under the hooks, and is generally circumscribed by a particular line or depression. The lunula presents certain peculiarities which it is often of consequence to attend to, in order to distinguish certain species otherwise apt to be confounded with one another. Its form is various, sometimes *cordiform,* a shape which almost peculiarly belongs to inflated and subglobular species; sometimes *lanceolate*, sometimes very narrow, especially in species whose shells are flattened. The lunula is very rarely prominent, unless it be towards the centre. Sometimes it is superficial, pretty frequently depressed, and there are a few genera or species in which it is deeply hollowed.

5. The *corslet* occupies a part of the superior and posterior edge of the shell. It is only met with in the Dimyaria; it is not so accurately bounded as the lunula; it is also wanting in a great number of genera, in which its presumed position is arbitrarily determined. It is towards its upper part that the nymphæ are observed in those species whose ligament is external.

In a very considerable number of Monomyarians the lunula and corslet are replaced by certain projecting parts to which the name of *auriculæ* or *auricles* has been given. These occur more especially in the Pecten family— the *Pectinites* of Lamarck; they are distinguished into anterior and posterior, and they are frequently unequal.

If we now turn to the particulars of the external surface of the shell of the conchifera, we shall find many points worthy of being attentively noted. In a very great number this surface is covered with a thin and frequently deciduous lamina of a subcorneous and often filamentous substance, to which the title of epidermis has been given. This matter is secreted by the most external edge of the mantle, but observers have not yet stated in what manner the secretion takes place, and what means the creature employs to make this epidermis adhere so strongly to its shell. The epidermis often occurs both of considerable thickness and extent (Glycimeris, Solemya), and thus constitutes an important portion of the shell. In other genera the epidermis appears to be wanting entirely, and in others bears some resemblance to velvet of thicker or thinner pile, and then consists of a large quantity of short hair, standing erect, and more or less closely set. In some species these hairs become more scanty, but increase greatly in length, as we perceive in certain Archidæ and Bucarides. When it occurs in certain species the successive growths of which are manifested by irregular ridges, the epidermis is irregularly squamous. The epidermis is insufficient to furnish any generic character that can be depended on; for there are certain extremely natural genera in which some species are covered with it whilst others are entirely naked.

The other particulars of the external surface of the shell are soon glanced at: they consist of *striæ*, *ridges* or *ribs*, and *furrows*, which, according to their direction, are distinguished into *longitudinal* when from the hook they run towards the inferior margin, and *transverse* when they follow an opposite course, that is to say, when they run from before backwards; they are *oblique*, again, when they follow a line in any way inclined to the longitudinal or the transverse. These *striæ*, *ridges*, and *furrows*, may cross one another, and the shell is then *trellised*. They may also severally present a great variety of particular appearances, the definitions of which may be found in the ordinary elementary works on Conchology, but which may all be learned much more rapidly from even a very moderately attentive study of the shells themselves than from any written description, however minute and accurate.

Internal surface.—The inner surface of bivalve shells is commonly smooth and polished, and often presents different colours which depend on the secretion of that part of the mantle which produces the solid laminæ of the inner surface. The greater number of shells are white within, and many of them are nacreous or like mother-of-pearl. Mother-of-pearl would appear to be the consequence of a molecular arrangement of the calcareous matter intimately united in a constant ratio with the animal matter by the combination of which the shell is formed. The proportion of the two substances does not appear to be the same in the non-nacreous and the nacreous shells; there are some which afford a much larger proportion of calcareous, and others which yield a much larger proportion of animal matter when analysed than is usual. Naturalists are now generally aware of the experiments, an account of which is to be found in the Philosophical Transactions, from which it appears that the nacreous lustre is owing to the decomposition of light by an infinity of asperities of excessive minuteness which beset the surface of the shell. It has, indeed, been found possible by means of an impression from a mother-of-pearl surface taken in sealing-wax especially, to transfer the power of exhibiting corresponding phenomena to the surface of the wax.*

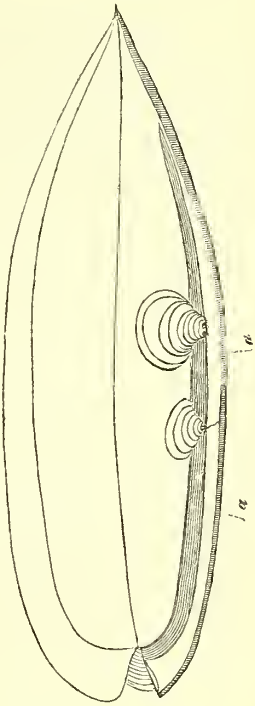
There is a variety of characters exhibited by the interior of the valves which it is of consequence to be familiar with. In shells which have belonged to dimyary mollusks, two muscular impressions of variable depth are constantly to be found in the interior. Sometimes they are so superficial that they escape an examination which might even be characterized as minute. One of these impressions is on the anterior side of the shell, the other on the posterior. They are generally subrotund; sometimes, however, they are elongated, which serves as an announcement that the muscles were flattened. In some genera these muscular impressions are of a particular form, as may be observed in the Lucina for example. It is a circumstance worthy of observation that the muscles of the animal shift their place and come forward in the shell in proportion as it grows, and it might have been concluded, *a priori*, that this could not be otherwise, when the mode of increment peculiar to the class is taken into consideration. On escaping from the ovum, a conchiferous mollusk is already provided with its shell, of course of very small size, and its two adductor muscles; and the relations of these muscles to the shell and the other internal organs are the same as at every subsequent period. When the animal has attained to some lines in length, and by the lapse of time to much larger dimensions, did not the muscles undergo a gradual displacement the shell would be found as thin at the summit as it was on escaping from the egg, and the muscles prolonged into the interior of the hook. Now, not only does the shell go on increasing in thickness and the hooks fill up, but observation shows that the adductor muscles always preserve the same relations and the same proportions. To study in the best possible manner the successive displacements of the muscular impressions, the best mode is to saw a fossil oyster-shell lengthwise in a line passing from the summit through the centre of the muscular impression. The impression will then be seen beginning towards

* [We have heard this point disputed. The power which the sealing-wax had certainly gained in some instances of exhibiting the mother-of-pearl lustre was afterwards shown to depend on the wax having detached a minute film from the surface upon which it had been pressed.—Ed.]

the summit and increasing gradually in its dimensions, so as to form a long triangular imprint, running obliquely through the thickness of the shell. When, at a very early age, the shell was extremely thin, the muscular impression existed very near to the external surface; but in proportion as the animal has become older, and new layers of calcareous matter have been successively added to the former, the muscular impression is found to have become farther and farther removed from the external surface. It is generally on the surface of the muscular impressions, and in the substance of the adductor muscles themselves, that those peculiar solid and highly prized excrescences called *pearls* are produced. These excrescences are engendered in a very considerable number of genera, and it is to be presumed that they may occasionally exist in all; it is, however, among the Monomyaria that pearls are most constantly formed.

Various causes have been assigned to explain the formation of pearls. But it seems enough to be aware in a general way of the manner in which bivalve shells grow to understand how pearls are produeed. Their production, it would appear, may be assigned to some accident happening to the animal; sometimes a few grains of sand getting between the mantle and the shell prove nuclei for their formation, but still more frequently they are consequences of perforations made by a speeies of Annelidan, to the attacks of which bivalve-shelled animals are obnoxious. In either case the animal, feeling itself injured, deposits over the grain of sand or the small orifice made by the Annelidan, a thin layer of nacreous matter, secreted accidentally and superabundantly with reference to its regular laminæ of progressive growth. In eonsequence of this, the shell at the point where the grain of sand lodges or where it is wounded acquires more than its usual thickness. This thickening, from the mere fact of its presence, becomes a permanent cause of excitement to the mantle of the animal, so that this organ goes on secreting an unusual quantity of calcareous matter, in consequence of which there results an elevation that increases with the age of the animal, so much the more rapidly as the annoyance has been greater and more permanent. When the mass has increased so much as to penetrate somewhat deeply into the substance of the organs, it is then apt to go on increasing by depositions of nacreous matter upon one of its extremities, by which we have pedunculated and elongated pearls produced. Zoologists have also asked how those pearls that are found perfectly free in the interior of conchiferous mollusks were formed. We shall first observe that these pearls are met with more especially in the substance of the adductor muscles; now if it be remembered that these muscles shift their place in proportion as the animal grows, it may readily enough be allowed that a pediculated pearl developed on the surface of the muscular impression itself, might be detached from its connexion with the shell by the advance of the muscle, become free in the substance of this muscle, and there continue to increase with more or less rapidity. This explanation, which we advance for the first time, appears to us sufficiently plausible; but, before admitting it as an established fact, it would be well to institute some experiments in regard to the successive changes of position undergone by the adductor muscles of a conchiferous animal.

Fig. 369.



The mantle, as we have seen, is attached to the shell by a determinate portion of its surface. In the Dimyaria the part that is adherent is not far from the thickened edge of the mantle; it adheres by means of the small muscles which regulate its contractions, as well as those of the tentaculary papillæ with which it is commonly fringed. In the Monomyaria the adhesion of the mantle is situated much higher, and very nearly at the place where the lobes of the mantle are detached from the general mass of the body. From the adhesion of the mantle to the shell there results a linear impression, to which M. de Blainville has given the name of *palleal impression;* in the Dimyaria it extends from before backwards, from the anterior to the posterior adductor muscular impression, following the circumference of the edge. This linear impression is simple when it presents no inflexion in its course. In a considerable number of the Dimyaria it is observed to form a notch of different depths in different species, directed towards the mantle. This notch appears to be produced, as we have already said, by the proper retractor muscle of the siphons.

Besides the muscular impressions of which we have now spoken, several others of much less importance have been particularized in the greater number of the conchiferous mollusks. All the species that have a foot have peculiar muscles to move this organ, and these have their fixed point of action on some point of the interior of the shell. They are generally divided into two principal fasciculi; the one runs to be inserted within the hooks, the other in the Dimyaria proceeds to be attached before and above the posterior adductor muscular impression. In the Monomyaria, the foot of which is generally rudimentary and without use, we observe nothing more on each side of the body than a single small fibrous fasciculus, the impression of which is found on the inside of the hooks. In some genera of Dimyaria, and particularly in the Unio, we observe three and sometimes four muscular impressions belonging obviously to the adductor muscles of the valves, which are occasioned by the anterior adductor muscle in particular being divided into two fasciculi, often of unequal size, as in certain Uniones, and sometimes equal and of considerable magnitude, as among the Iridines.

From the summary and concise view we have taken of the principal facts in the organization of the Conchifera, very important conclusions may be drawn with reference to the classification of these animals.

Taking the Conchifera, properly so called, and looking narrowly into that which is of most importance in their organization—the nervous system, we find two principal modifications, coinciding in a very remarkable manner with the number of the muscles. This number of the muscles, permanently proclaimed by the impressions they leave on the shell, presents an important character by means of which, while we define their limits somewhat more strictly, we feel authorized in retaining the two grand orders of Lamarck,—the Conchifera Dimyaria, and the Conchifera Monomyaria. A fact of some importance, and brought to light by the observations of Poli, is that a small nervous ganglion exists at the point of commissure in those acephalous mollusks which have the lobes of the mantle conjoined. This peculiarity gives new consequence to the characters drawn from the conjoined or disunited state of the lobes of the mantle. Unfortunately the circumstance is not always indicated upon the shell; it is, in fact, only obvious upon those inhabited by siphoniferous animals; it is quite inappreciable upon those the inhabitants of which have siphons so short as not to require a particular retractor muscle to draw them within cover of the shell. With regard to the other organic characters which furnish data available in classifying the Conchiferous mollusks, these are all of so little permanency that they are only useful in supplying secondary hints for the arrangement of families and genera. Thus neither the branchiæ nor the heart present any character susceptible of generalization or of contrast. Better data might perhaps be obtained from the conformation of the organs of digestion; but these organs have hitherto been examined in comparatively so small a number of genera and species that they cannot be brought forward usefully in supplying characters for a general classification. If, as we ourselves feel inclined to do, the hinge be taken as the point of starting in the Pholades, this part may be made the means of giving excellent characters in its principal modifications for the establishment of genera. It is, indeed, very remarkable that we should find the characters as indicated by the hinge almost constantly in harmony with those afforded by the rest of the organization; and with a few exceptions, relative to several extremely natural families, that of the Unios for example, all that is valuable in the generic characters generally may be preserved along with the characters supplied by the hinge. Another character which may be usefully employed in classification is assumed from the regularity or irregularity of the shell of the animal; in generalizing upon this, like groups are obtained in the two principal divisions of the Conchifera, and the two principal divisions of the classification are referred to the simplicity or exactness of the dichotomy, whilst natural groups are preserved as much as may be in the linear arrangement.

Method, it must ever be remembered, is an artificial means of introducing order among a series of observed facts, and of approximating, according to the analogy of their organization, the beings which nature has scattered over the face of the earth; method is a human creation altogether, and in this light must it be viewed. To be all it ought, every known fact must be included, and the greatest possible amount of organic relationships between the individuals of each great class must be indicated. In an exposition of facts seriatim, and as they occur in a book, every thing has to be arranged in sequence, and therefore in the linear mode, now so generally followed by naturalists. In this way, however, it is impossible to express the enchainment, the inosculation, so to speak, of the different groups. To counterbalance this inconvenience, we are of opinion that the classification ought to be made with lateral offsets, now terminating abruptly, now divided once or twice, sometimes inosculating variously, and again, departing from a common trunk, disposed in one case in a right line, in another in a curved line, and in a third in a circle. We conceive that it is according to these new views only that the acephalous mollusks can be properly arranged; it is accordingly upon the principles just announced that the following table is constructed.

Although in the present state of our knowledge of these animals many important particulars are still unquestionably wanting, this division of the molluscous tribes nevertheless presents fewer gaps than any of the others, inasmuch as opportunities have occurred of examining some one or other of the animals belonging to the whole of the genera.

CLASSIFICATION OF THE CONCHIFERA.

- MOLLUSCA ACEPHALA BIVALVIA
  - *DIMYARIA*
    - *The lobes of the mantle united in a greater or less degree posteriorly*
      - TUBICOLÆ: Aspergillum, Clavagella — Fistulana, Galeonnucca, Saxicava, Petricola, Venerupis‡ } PETRICOLÆ
      - PHOLADARIÆ: Septaria, Teredo, Teredina, Pholas
      - OSTEODESMATA: Pholadomya, Osteodesma, Periploma, Anatina, Thracia — *Pandora; Thracia, Corbula*, Mya, Lutraria } Anatinella
      - MACTRACEÆ: Lutraria, Mactra, Mesodesma, Crassatella, Erycina, Amphidesma
      - TELLINIDES: Tellina, Psammobia, Donax — Psammobia — SOLENACEÆ: Solenertus, Panopœa, Solen, Solemya, Glycimeris
      - CONCHÆ: some — Astarte†, Venus‡
      - CYCLADES: some — Cyclas; Cyrena Cyrenella‖, Galathea
      - CARDIACEÆ: Cypricardea, Isocardea, Cardium§ > Opis
      - TRIDACNEÆ: Tridacna, Hippopus
    - *The lobes of the mantle disunited*
      - NAYADES: Cardita, Unio
      - TRIGONEÆ: Trigonia, Nucula
      - ARCACEÆ: Petonculus, Arca, Cucullea
      - MYTILACEÆ: Mytilus, Pinna, Avicula
  - *MONOMYARIA*
    - *Having a foot*
      - MALLEACEÆ: Malleus, Valsella, Crenatula, Perna — Gervillia, Inoceramus, Catillus
      - PECTINIDES: Lima, Pedum, Pecten, Hincistes, Plicatula, Spondylus
    - *Having no foot*
      - OSTRACEÆ: Ostrea¶

- †Corbis, ‖ Lucina, Ungulina } LUCINIDÆ
- Myochama, § Cleidotherus, Chama, Diceras*, Etheria } CAMACEA
- *Spherulites, Hippurites, Corprina } RUDISTES
- ¶Placuna, Placunanomia, Anomia† } PLACUNIDÆ

†Terebratula, &c.

This tabular view of the classification exhibits certain particulars, upon which we deem it necessary to offer a few explanatory remarks. As we said before, the series as a whole may be regarded as a common trunk, from which various branches spring, sometimes anastomosing, sometimes ending abruptly. It is thus that from the *Clavigella* we observe a lateral line departing, formed of the genera *Fistulana*, *Galeomma*, and those of Lamarck's family of *Petricola*. These genera descend parallel to the common trunk of the classification, so as to approximate in as great a degree as possible the genus *Venerapis* to the genus *Venus*. The genus *Pandora* has numerous analogies on one side with the *Corbula*, but it has also many with the members of the genus *Osteodesma*, on which account it is made to depart laterally from the *Corbula*, and to ascend towards the *Osteodesmata*. The *Latraria* are also variously related to several genera of the *Osteodesmata*, and this genus is joined to that of the *Thracia* by means of the genus *Anatinella*, which we place crosswise to connect the genera just mentioned. In the *Mactracea*, we pass without any very great stride from the *Lutraria* to the *Mactra*, from the *Mactra* to the *Erycina* and to the *Amphidesma*. Farther, in order not to interrupt this series of relationships, we place upon a lateral line departing from the *Mactra* the two genera *Mesodesma* and *Crassatella*. Every naturalist knows how great the resemblance is between the flat and broad *Solcus* (*Soletellina*, De Blainv.) and the *Psammobiæ;* but we also know that the genus *Psammobia* has so many analogies with the family of the Tellinida, that it is impossible to detach it from this family in order to include it within the family of the Solenaceæ. To avoid interrupting the relations of this genus to those of the *Solen* family, we have recourse to an ascending line composed of the genera *Solenertus*, *Panopæa*, *Solen*, *Solemya*, and *Glycimeris*, by which means we approximate, as much as possible, these last genera to the families Pholadia and Osteodesmata, with which they have in fact unequivocal relationships in point of organization. We consider the family of the *Lucinidæ* as a lateral and truncated branch of the *Conchidæ*, divaricating from the genus *Astarte*. With regard to the *Cyclada*, we place the genus *Glaucoma* of Mr. Gray laterally, between the *Cyrenas* and the *Venuses*, so as to establish the connexion between the two genera; whilst departing also from the genus *Cyrena* we place our genus *Cyrenella* obliquely in order to make it join that of *Lucina*, this genus of *Cyrenella* being to *Cyrena* and *Lucina* that precisely which the genus *Glaucoma* is to *Cyrena* and *Venus*. To us the family of the *Chamacea* is a lateral offset from that of the *Cardiacea*, and although the *Etheriæ* and the family of the *Radistes* are in reality among the number of those Conchiferous mollusca which have the lobes of the mantle disjoined, still as they do not immediately arrange themselves in any particular part of this section, we have placed them to the side in continuation of the family of the *Chamacea*, but underneath them. The family of the *Ostracea* we now believe to consist of the single genus *Ostrea*, and we propose under the name of *Placunidæ* a family containing the three genera *Placuna*, *Placunonomia*, and *Anomia*, which according to our views constitute a descending and lateral line really intermediate to the *Conchifera* and the *Brachiopoda*.

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(G. P. Des Hayes.)

CONTRACTILITY. — Since it has been generally understood, that all the most striking and conspicuous movements which take place in living animals, depend on peculiar contractions of certain of their solids, the circumstances of these contractions, the causes by which they are excited, and the laws by which they are regulated, have been justly regarded as objects of the highest interest, and of fundamental importance, in physiology. The term Irritability was employed by Haller and his followers, to denote all such contractions in living bodies, as they judged to be peculiar to the living state; but more recent inquiries have shewn the necessity of distinguishing different species of these contractions; and the more comprehensive term Contractility is now pretty generally employed. To this the epithet Vital, in physiological discussions, may usually be understood as prefixed.

It is to be remembered, however, that several of the animal textures are endowed with a pro perty of contraction, in certain circumstances, which is not peculiar to their living state, but subsists as long as their structure remains unaltered after death; and the distinction between the phenomena resulting from this cause, and those which are strictly vital, has not always been accurately observed. Thus many of the soft animal textures, muscles to a certain degree, tendons and ligaments in a greater degree, and arteries in a still greater degree, are elastic, and liable to contractions from that cause when stretched. The *Contractilité de Tissu* of Bichat is in most cases to be considered simply as Elasticity, although in some cases (as when he assigns this property as the reason of the retraction of the cut extremities of a living muscle or of the stiffening of limbs after death,) he gives this name to contractions which are strictly vital. Almost all animal substances are liable to contraction from heat, and from the application of various chemical agents which affect them as astringents, to which property Bichat gave the name of *Contractilité par racornissement;* and it is easy to perceive that this property also, although persistent in the perfectly dead body, and therefore independent of life, may give occasion to contractions which may sometimes be mistaken for indications of the strictly vital contractility.

Confining our attention, however, to such contractions of the solids of organized bodies, as are exhibited by them only in their living state, i. e. so long as they present that assemblage of phenomena, to which we give the name of Life,—we proceed to state the facts which seem to be most important and best ascertained, *first*, as to the modes in which they are excited; *secondly*, as to their phenomena, and varieties; *thirdly*, as to the conditions necessary to their manifestation; and, *lastly*, as to the laws which regulate them.

I. It is universally known, that the most striking examples of vital contractions are seen in the effects produced by various *stimuli* acting on muscles, particularly those of voluntary motion, and the heart. The essential characters of muscular fibres, their composition nearly akin to the fibrin of the blood, their arrangement in parallel fasciculi, which are bound together by cellular membrane, their soft texture, and slight elasticity are also generally known. The change excited by stimuli acting on them is a contraction in the direction of the visible fibres of the muscle, which in the healthy state always rapidly alternates with relaxation; and by these two circumstances,—the excitation by stimulus, and the quickly ensuing relaxation,—we distinguish that form of Vital Contractility, to which the term *Irritability* is most correctly applied.

The stimuli which produce this effect are very various; and the experience of our own bodies points out the obvious distinction of these into *physical* and *mental*. Of the first kind, air and water, especially if aided by heat, act decidedly in this way; but those which have been chiefly used in experiments are, distension, especially in the case of the hollow muscles, such as the heart or bladder,—chemical acrids, such as acids, alkalies, various alkaline, earthy, or metallic salts,—and electricity or galvanism. The effect of all these stimuli is much increased by their being *suddenly* applied.

It has also been long known, that many muscles are excited to contraction by such stimuli, when applied to certain *nerves*, entering their substance, or to certain parts of the spinal cord or brain, even more effectually than by applications to themselves; and likewise, that it is only when those nerves are entire, up to the brain, that those muscles which are naturally obedient to the mental stimulus of the Will, can be excited by voluntary efforts.

From these different modes of excitation of the contractile power of muscular parts, different names have been given to the power itself, as by Haller, who applied the term *Vis Tonica* to the contraction from distension, *Vis Insita* to the contraction from irritation of the muscular fibres themselves, *Vis Nervosa* to the contraction from irritation of a nerve, and *Vis Animalis* to the contraction from volition, acting at the brain and transmitted through a nerve; or again by Bichat, who applied the term *Contractilité Organique Sensible* to the contractions excited by any kind of irritation, acting on muscular fibres themselves, and the term *Contractilité Animale* to those excited by stimuli, whether mental or physical, acting on the nerves, spinal cord, or brain. But it is obviously more correct to distinguish the different varieties of the vital power according to the phenomena, which the contracting part presents, than according to the manner in which the contractions are excited; and therefore those terms have fallen much into disuse. In most instances, it is the same vital power of Irritability, as above defined, which is called into action in these different ways.

It is only of late years, that it has been fully ascertained, as to the excitement of vital contractions through nerves: 1, that it is, almost exclusively, in the case of muscles which are naturally subject to the Will, that even physical irritation, *confined to the nerves*, has power to excite contraction; and 2, that these muscles have nerves, or nervous filaments, from two distinct sources, viz. from the anterior and posterior columns of the spinal cord, and their prolongations within the cranium; and that it is by irritation of the first of these only, (or almost exclusively,) that the muscular contractions are excited.* From these facts, it appears obvious, that the grand and eternal law of separation, as Haller calls it, of the Voluntary and Involuntary muscles, consists essentially, not in different powers of the muscular parts, but in different endowments of the nervous filaments which enter them.

In regard to the excitation of muscular contraction through nerves, it is also to be observed, that although the action of muscles in obedience to the *will* is the most obvious and striking example, in the living body, where the intervention of a change in a nerve is known to be an essential condition of the act, yet there are many examples of movements, performed by voluntary muscles, in obedience to mental stimuli, but not to volitions,—to *sensations*, or other *involuntary* acts of mind, even in opposition to efforts of the will. These constitute a very important class of vital motions, and are known to be equally excited through the motor nerves of the muscles concerned in them. Of this kind are not only the irregular agitations of the limbs produced by tickling, or the convulsive writhing of the body from pain, but also, such regular and admirably precise movements as shrinking when pain is excited

* See Mayo's Outlines, 2d edit. p. 50 et seq. and Sir C. Bell, Phil. Trans. 1826.

on the surface, closing the eyelids when the eyes are offended by bright light, swallowing, breathing, coughing, sneezing, vomiting, expulsion of fæces and urine, &c. consequent on certain sensations of the fauces, lungs, air-passages, nostrils, stomach, rectum, or bladder. Such muscular actions, excited by irritation of *distant* parts, have been generally but vaguely described as the effects of Sympathies of one part of the living body with another. It is well ascertained that they are effected through the motor nerves (or certain of the motor nerves) of the muscles concerned in them; and their dependence on the Sensations, and therefore on the sensitive nerves, of the parts from the irritation of which they originate, has been sufficiently illustrated by Haller, Whytt, Monro, and others.*

It has also been observed, by Haller and Whytt, but more frequently and carefully by Legallois,† Flourens, and Mayo,‡ that in many animals, (most remarkably in cold-blooded, or young warm-blooded animals,) even after the removal of the brain, as long as the circulation can be maintained, movements of the kind now in question go on, or may be excited by irritation of the surfaces; and that if the spinal cord be divided into several parts by transverse sections, such movements may still be excited in the muscles supplied from each part, by irritation of the portion of the skin which has its nerves from that part of the cord. These facts have (as is believed) usually been thought to denote, that a certain degree of Sensation remains under these circumstances, in connection with the living state of the spinal cord, or of portions of the spinal cord, and medulla oblongata, independent of the brain; and that it is still through the intervention of sensation, that irritation of the surface of the body excites any contraction of muscles. Dr. Marshall Hall has lately described phenomena precisely of this description, under the title of Excito-motory phenomena, and as proofs of what he terms the Reflex Function of the Spinal Chord§—a power of exciting contraction in muscular fibres connected with it, which he supposes that organ to possess, equally independently of sensation as of volition;|| and as it seems hardly possible to be quite certain of the existence of Sensation in the case of the mutilated animal, this language is perhaps philosophically correct; but the probability of the existence of Sensation in such circumstances must be allowed to be very great; and at all events, that sensation is an essential part of the connection between the irritation of distant parts, and the excitement of involuntary muscular contractions of voluntary muscles, for useful purposes, in the entire and healthy body,—may be held to be a point well established by the observations of Haller, Whytt, Monro, and others, on such *sympathetic* actions. Accordingly, those actions, in the entire body, which Dr. M. Hall ascribes to the reflex function,* are the same, or similar to those, which have been fully treated by Dr. Whytt and others as sympathetic actions, or actions of voluntary muscles excited by sensations.

But Dr. Hall has fixed the attention of physiologists on this class of facts, and has illustrated by experiments their independence of the Brain, and dependence on the Spinal Cord exclusively, and in this conclusion he is supported by many facts previously recorded by Le Gallois, Magendie, Flourens, and others.

It is further to be observed, that the contractions of voluntary muscles, which are supplied by the nerves of the Symmetrical class of Sir C. Bell, while they are excited through the one set of filaments comprising those nerves, are made *known to our consciousness* by the others or sensitive filaments, and constitute the important class of Muscular Sensations. Of the movements of the strictly involuntary muscles, the heart, stomach, and bowels, and even the bladder, (supplied by irregular nerves,) we have, in the perfectly healthy state, no intimation, although they frequently become perceptible to us in disease, or when over-excited. But contractions of some of these involuntary muscles also are pretty certainly excited by certain Sensations, as, e. g. a certain degree of antiperistaltic movement in the stomach by the feeling of nausea, and a certain movement of the pharynx and œsophagus by the sensations in the fauces, which prompt the act of deglutition; and in such cases, although not attended with consciousness, they are in all probability excited through the nerves of these muscular parts. Accordingly, the pharynx and œsophagus have been observed by Mr. Mayo, and the stomach by Breschet, Milne Edwards, and others, to be exceptions to the general rule of involuntary muscles being inexcitable by irritation of their nerves.

The old distinction of muscles into Voluntary, Involuntary, and Mixed, is very deficient in precision, so far as the last class is concerned. The true distinction is, of *muscular contractions*, into those excited in the natural state by Mental Stimuli, and through the intervention of Nerves (qui soli in corpore mentis sunt ministri)—and those excited by Physical Stimuli, acting on the muscles themselves, whereas the intervention of nerves is a theory, not an established fact. The first class admits obviously, from what has been stated, of a division into movements excited by the Will, which depend on the Brain, and movements excited by involuntary mental acts, especially by Sensations, which depend only on the Spinal Cord and medulla oblongata. The Will acts only on

* It is obvious that such motions, excited directly by sensations, cannot be accurately distinguished from those voluntary actions which are called Instinctive, as being prompted by the instincts, distinct from strictly intellectual acts, which are linked by nature with the sensations of certain parts of the body.

† Expériences sur le Principe de la Vie.

‡ Outlines of Physiology, second edit. p. 282, and Anat. and Physiol. Comms.

§ Phil. Trans. 1833, p. 635.

|| See particularly p. 640.

* P. 653 et seq.

muscles provided with sensitive nerves, by which the mind is informed of the contractions, and so enabled to regulate or guide them. The Sensations act chiefly on this description of muscles likewise, but partly also on muscles the nerves of which give no such distinct intimation of their contractions, and which are uniformly and strictly involuntary; and the chief excitants of this last class of muscles in the Animal Economy are physical stimuli, applied to themselves and to their lining membranes.

II. In regard to the vital power or property of Irritability, as exhibited in any of these ways, the following facts demand particular notice.

1. The minutest fibres, of which the muscles, exhibiting this property, consist, or what have been called by some authors the *primary filaments* of muscular fibres, appear under the microscope to consist of rows of globules, or at least to be marked by transverse striæ, at equal distances.

2. When contraction takes place, these filaments, or rows of globules, are thrown into a zigzag form; the angles being always at the same points on each contraction, and being generally obtuse, rarely and only on occasion of very forcible contraction, acute.* At the points where these angles are formed, the filaments are crossed, according to the observation of Prevost and Dumas, by nervous fibrils; but it is important to remember, that this last observation has been made only on muscles of voluntary motion, and on them only in cold-blooded animals, where they are somewhat translucent.

3. According to the best observations, not made on entire limbs or even entire muscles, which involve various fallacies, but on small portions of muscles, removed from living bodies, it appears that no alteration of the bulk of the filaments attends this alteration of their form, so that neither the size nor distance of the particles or globules appears to be changed, but merely their position in regard to one another.†

4. When by any stimulus, applied to muscular fibres, the filaments directly stimulated are thrown into action, the contractions very generally and rapidly extend to many others in their neighbourhood, frequently even to the whole muscle of which they form a part; but the contractions of single fibres appear to be of short duration, and the more enduring efforts to be made by many short successive contractions and relaxations or vibrations of the individual fibres.

From these facts it would appear, that each exertion of this property of Irritability essentially consists in a greatly increased attraction among the particles or globules constituting the muscular fibres, and alteration of the direction in which this attraction acts,—rapidly communicated from one particle to another, both along the same fibre, and among adjacent fibres,—and rapidly succeeded by repulsion, or return to the previous state of the cohesive attraction existing among these particles.

When a muscular mass, consisting of many such fibres, is thrown into this kind of action, it is easy to understand that its breadth and thickness, and its rigidity or resistance to compression will be increased; that its extremities will be approximated; and that if it be disposed around a cavity, containing a fluid and provided with an outlet, that fluid will be expelled. It is by such contractions, that all the more conspicuous movements, even of the organic life, of the higher animals, are performed, and that their locomotive and vocal powers are exerted; and it is worth while to pause for a moment to consider the almost inconceivable amount of moving power, and rapidity of motion, which various facts indicate in muscles thus contracting, whether under the influence of the will, or from other stimuli.

It seems well ascertained that the contractions of the left ventricle of the human heart, in its ordinary unexcited state, are sufficient to expel its fluid contents, in free space, a distance of 7½ feet, and to balance a weight of above 50 lbs.; and this power is exerted regularly more than once in every second, and often, even independently of disease, twice in every second, during the whole of human life. The ordinary action of the left ventricle of the Whale's heart suffices to expel, according to Dr. Hunter's statement, at each pulsation, above ten gallons of blood, with a great velocity, through a tube of a foot in diameter.

Two instances given by Haller, and quite within the limits of ordinary experience, sufficiently exemplify the great power occasionally exerted by voluntary muscles; and which will appear the more extraordinary when it is remembered, that the direction of muscular fibres, as regards the line in which they are to act,—the points of their insertion into the bones they are to move,—and the line in which they act, as regards the motion which they give to these bones,—are all, very generally, such as to render their action disadvantageous, and require a greater amount of moving power than might otherwise have been necessary. The instances recorded are, the case of a man, who could raise a weight of 300 lbs. by the action of the elevator muscles of his jaw; and that of a slender girl, afflicted with tetanic spasm, in whom the extensor muscles of the back, in the state of tonic contraction or opisthotonos, resisted a weight of above 800 lbs., laid on the abdomen with the absurd intention of straightening the body. In some of the lowest classes of animals the intensity of the muscular power appears to be greater than in any of the largest. Thus, a flea has been known to leap sixty times its own length, and to move as many times its own weight.

* This appearance, with slight variations, has been repeatedly seen, both in warm-blooded and cold-blooded animals, in the lower classes and even in the infusory animals, under the microscope.

† See Prevost and Dumas, in Journal de Physiologie, tom. iii.; and Mayo's Outlines.

Again, the rapidity of the changes of position of the component particles of muscular fibres may be estimated, although it can hardly be conceived, from various well-known facts. The pulsations of the heart can sometimes be distinctly numbered in children at more than 200 in the minute; and as each pulsation of the ventricles occupies only one-third of the time from the commencement of one pulsation to the commencement of the next, this implies that each contraction takes place in $\frac{1}{600}$th part of a minute, or that ten times in each second, for many hours together, the whole of the convoluted muscular fibres of the ventricles must be thrown into folds, and again smoothed out. Again, it is certain that by the movements of the tongue and other organs of speech, 1500 letters can be distinctly pronounced by some persons in a minute. Each of these distinguishable sounds must require a separate contraction of muscular fibres; and the production and cessation of each of these sounds must imply, that each separate contraction must be followed by a relaxation of equal length. Each contraction must, therefore, have been effected in $\frac{1}{3000}$th part of a minute, or in the 50th part of a second. Haller calculated that in the limbs of a dog at full speed, muscular contractions must take place in less than the 200th part of a second, for at least many minutes in succession.*

But the property of Irritability, which acts throughout so great a portion of the animal creation, as a moving power of this extraordinary efficiency, is not the only contractile power, which certain organic textures possess, or which the conditions of their existence require them to exert during the living state. Even in muscular fibres themselves, in certain organs, and still more in other textures of animal bodies, contractions are often observed, peculiar to the living state, but differing essentially from those which come under the definition of Irritability already given.

In all the different tribes of animals, indeed, differences in the contractile power of the different living solids may be observed, exactly corresponding to their circumstances and wants. The slow and languid movements of the bodies of most of the Zoophyta, and the rapid vibrations of the Ciliæ with which parts of many of these animals (particularly of the order Infusoria) are provided, are examples, even in the lowest class, of the great variety of moving powers, with which the living solids of different animals are endowed.

In the human body, and analogous animals, it is obvious that the contractile power exerted by the stomach and intestines in performing their peristaltic movements, although of the same general characters as that of the heart,—the contraction of each portion of the tube being followed by a relaxation of that portion and a contraction of the portion next in advance,—is yet materially different; both contraction and relaxation in the peristaltic movement being of longer and less definite duration, and of more variable extent. In the bladder and in the uterus, in the healthy state, we see contractions excited by peculiar stimuli, and repeatedly recurring as the actions dependent on them proceed, but not alternating with any obvious elongation of the fibres, and terminating in a much greater and more permanent shortening of the contracting fibres, than is observed in other muscular organs.

Again, in the state of any voluntary muscle, when the distance of its extremities is permanently shortened (as by an ill-united fracture), in that of the sphincter muscles, or of an artery when emptied of blood, we see a *permanent* contraction, requiring no stimulus to excite it, shewing itself whenever a distending or elongating power is withdrawn, and relaxing only at the close of life. The numerous experiments of Dr. Parry on the condition of arteries immediately after death (contained in his Treatise on the Arterial Pulse) afford the most precise information that we have as to this last property.

From such facts it appears obvious that *three* distinct modes of contraction, all strictly vital, may be observed in different textures of the body, or even in the same texture under different circumstances: *first*, that already considered, to which the term *Irritability* is strictly applied, and which is best exemplified in the actions of the voluntary muscles and the heart; *secondly*, that which may be termed *simple Contractility*, where contraction is induced by a stimulus, but takes place more slowly, and is nearly or quite permanent; and, *thirdly*, that which has been accurately described by Dr. Parry and others under the title of *Tonicity*, which requires no stimulus to call it into action, but takes effect whenever a distending power is withdrawn, and continues until life is extinguished. The second of these forms is seen, not only in the bladder and uterus, but in the arteries under certain irritations, perhaps in other textures, and probably also (from certain stimuli) in the fibrin of the blood during coagulation.* The last is clearly, as Dr. Parry's experiments have shewn, the chief vital endowment of arteries; and notwithstanding the doubts expressed on the subject by Dr. Bostock, several facts may be stated to show, that it is also an endowment of all muscular fibres. Thus, besides the permanent retraction, already noticed, of the fibres of a muscle the fixed extremities of which are approximated,—the retraction of the cut ends of a muscle divided during life,—the state of habitual preponderance of the flexor muscles of the body and limbs (which are the stronger) over the extensors during sleep,† and the stiffening or "roideur cadaverique" of the muscles after death,—seem to be clear indications of a tendency to contraction answering

* See Haller's Elem. Phys. tom. iv. p. 481.

* See Prater's Experimental Inquiries in Chemical Physiology.

† See Richerand's Physiology.

to the definition of Tonicity, not of Irritability. This last phenomenon, as it disappears before putrefaction begins, and as it is variously influenced by causes affecting vital action, is allowed to be a last exertion of vital power.

There are evidently slighter modifications or varieties of the powers which we have thus distinguished; but the distinctions now stated seem to be those which are sufficiently marked to demand separate names. Besides the muscular texture, some of the membranes, especially the skin, appear to be endowed with a certain degree of vital contractile power, although not with true Irritability. It is remarkable, that the greatest degree of contraction seen in muscular fibres, is in those which possess the property of simple Contractility rather than Irritability, viz. in the bladder and uterus more than in the intestines, and in these more than the heart.

III. As to the conditions, necessary to the maintenance of the contractile powers of living parts, it is in the first place obvious, that they are always dependent on the maintenance of the organization of these parts themselves. When the muscles waste, as from rheumatic inflammation, or from the poison of lead, as in colica pictonum, or when their texture is gradually altered, as by inflammation or in certain organic diseases occasionally affecting them, or more rapidly relaxed and injured by over-distension, they lose their contractile power more or less completely; and their power is likewise gradually diminished in old age, as their texture partakes of the gradually increasing rigidity.

Like all other vital actions, the contractions of moving parts are more immediately dependent on the maintenance of a certain temperature, varying in the different tribes of animals,—in all the warm-blooded (in the state of activity) probably confined within the degrees of 60 and 120 of Fahrenheit. They are dependent also on the regular supply of arterial Blood. The experiments of Stenon and others have shewn, that the power of muscles is rapidly extinguished when the arteries supplying them are tied. It has generally been supposed, since the time of Bichat, that venous blood, when it penetrates muscular fibres, is equally or even more rapidly noxious to them, than the denial of the supply of arterial blood; but the experiments of Dr. Kay* have shewn, that the contractile power of muscles, when failing from this latter cause, may be restored by the influx of venous blood, although in a less degree than by arterial,—and Dr. Marshall Hall has observed, that in hybernating animals whose respiration is suspended, the flow of venous blood through all the textures continues, and keeps up a certain degree of muscular power; so that the venous blood can only be regarded as less powerful in maintaining the irritability of muscles than arterial blood (probably because it is incapable of affording them nourishment), not as positively deleterious to them. The act of healthy Nutrition, by arterial blood, is therefore the main condition of the vital power of muscles, as of all other living solids. And it is important to remember that this vivifying influence of the living blood on the solids is evidently reciprocal; for when any of the vessels containing blood lose their vitality, as from injury, the blood then coagulates, as if drawn from the body.

There is a remarkable difference which has been long observed, in the different classes of animals, and even in the different states of the same animals, as to the consumption of oxygen by the blood on one hand, and the indications of muscular power on the other. The *activity* of muscular power (as indicated by the rapidity of the circulation and the energy of voluntary muscular exertions) appears to be, in general, in *direct* proportion to the amount of action between the air and the blood, being greatest in birds, greater in the mammalia than in reptiles or fishes; and greater in insects, where air is freely admitted into the interior of the body, and applied to the blood, than in the Zoophyta, or even the Mollusca, where there is less exposure of the blood to the air; and again, being greater in perfect animals than in eggs or pupæ, and greater in animals in a state of activity than in those in a state of torpor or hybernation. But on the other hand, the *endurance* of the muscular power, or tenacity of life, in whatever manner the vital principle is depressed or extinguished, is generally in the *inverse* ratio of the activity of muscular contractions, and of the amount of mutual action between the air and the blood. Thus the tenacity of life in reptiles and fishes is well known to be greater than in mammalia or birds,—in some of the lower classes, particularly the infusory animalcules, much greater than in any of the higher; in very young animals greater than in adults; and in hybernating animals, in eggs, and pupæ, greater than in any perfect animals.

Dr. Marshall Hall has observed, that in some of the lower classes of animals, such as Reptiles, the *degree* of muscular contraction induced by stimuli, as well as its duration, is greater than in the warm-blooded animals; and he has hence been led to lay down as a general principle the reverse of what has commonly been stated, viz. that the Irritability of muscular fibres is *inversely* as the quantity of Respiration. But this proposition seems to be too generally, if not incorrectly, expressed. It seems an unnecessary innovation in language, to assert that the irritability of muscular fibres is inversely as the activity of muscular contractions, or that the irritability in insects, where the blood is fully exposed to the air, is less than in the Zoophyta, where there is much less provision for respiration. In fact, the vital powers of contractile parts vary so much in different organs, even of the same animal, that it may be doubted whether any other general proposition can be laid down as

* Edin. Med. and Surg. Journal, vol. xxviii. and Treatise on Asphyxia, ch. iii.

to its connexion with respiration, than that of the greater activity of muscular action, on the whole, in those animals where there is much exposure of the blood to the air, and the greater endurance or tenacity of life where there is little.

The question, how far the Nervous System furnishes one of the conditions necessary to the maintenance of the contractile power of muscles, has long engaged the attention of physiologists, and been the occasion of much erroneous medical theory; but in the present state of the science, need not occupy much of our attention.

The doctrine of Cullen and many other systematic writers, that the muscles derive regular supplies of Irritability or vital power, through the nerves, from the larger masses of the nervous system, seems to be now pretty generally abandoned, although the terms Nervous Influence or Energy are still suffered to retain, in the language of many medical writers, a vague and indefinite meaning, derived from that apparently erroneous theory. When we remember, that after the nerves of a muscle are cut, the muscle continues irritable under stimuli applied to itself, or to the portions of nerves below the section, as long as it retains its organization unimpaired,—that section of the nerves leading to the heart has in very numerous experiments been found to produce little or no effect on its movements,—that these movements continue for hours after the head has been cut off, or even (as was first shewn by Dr. Wilson Philip) after both brain and spinal cord have been removed from the body, provided that the flow of the blood through the lungs is maintained by means of the artificial respiration,—that in hybernating animals (as Dr. M. Hall* has ascertained) when respiration is at a stand, the regular movements of the heart may continue for nine hours after the gradual but complete destruction of the whole brain and spinal cord,—and that there are many instances on record, of the human fœtus having come to a full size (implying long-continued and regular action of the heart), where neither brain nor spinal cord existed,†—it seems impossible to maintain the purely hypothetical proposition, that the *irritability* of muscles is dependent on an influence or energy continually flowing to them from the brain or spinal cord; ‡ and the only question that can remain is, whether the *irritation* of muscles is always effected through the medium of nerves, i. e. whether every stimulus which excites contraction in a muscle first acts on some of the nervous fibrils which enter it, and by exciting them throws the muscular fibres into action. An experiment of Brachet* has been thought to furnish evidence of the dependence of the heart's actions on the cardiac plexus of nerves, but is so liable to fallacy, and so much opposed to the experience of others, on the effect of injuries of the cardiac nerves, that the inference seems to have been generally distrusted.

Without presuming to decide absolutely on a question which still divides the opinions of physiologists, and without entering on various arguments which have been stated as furnishing probable evidence either on the one side or the other, we may observe,— 1. That the safe logical rule in such cases, is "Affirmantibus incumbit probatio;" and therefore it does not appear philosophical to teach, that the contraction of all muscles, on stimuli being applied to themselves, is owing to the intervention of nerves, until that intervention be proved. 2. That if the contraction of all muscles were excited through nerves, we might expect to find all muscles supplied with nerves, the mechanical irritation of which, in the living or newly killed animal, should excite that contraction. But it has been already observed, that in the case of the involuntary muscles, physical irritation of the nerves entering them (if strictly confined to the nerves) has very generally been found quite ineffectual for that purpose. This seems pretty clearly to indicate, that the power of exciting muscular fibres to contraction is an endowment peculiar to the nerves of the voluntary muscles, or at least enjoyed by them in a much greater degree than by others, and designed, not to render these muscles irritable, but merely to subject their irritability to the dominion of the Will.

The observation of Fontana on this subject, made as early as 1775, and in perfect accordance with the statements of Haller previously, and of many other physiologists subsequently, may still be quoted as more conclusive than any other which has since been brought forward. "If you open the chest of an animal, (a cold-blooded one answers best for the experiment) and stimulate as you please the nerves going to the heart, that muscle will neither accelerate its movements if it be moving, nor resume them if it be at rest,—even although it be prone to immediate contraction on its own fibres being touched. The nerves of the heart, therefore, are in no sense the organs of the movement of this muscle, as they are of other muscles. This experiment is certain, and the inference direct. It would be a contradiction to assert that the movements of the heart take place through the intervention of

* Philosophical Transactions, 1832

† See Brachet's Recherches sur le Système Nerveux, p. 36 & seq.

‡ Mr. J. W. Earle, in a "New Exposition of the Functions of the Nerves," has attempted to revive this theory. He trusts chiefly to an experiment, in which the irritability of muscles, exhausted by repeated irritation, was *not* recovered after their nerves had been cut. But this experiment is inconclusive, because the muscles had become inflamed and disorganized.—(See p. 70 and 71 of his work.) This experiment has been lately repeated in Edinburgh, with precautions to prevent the inflammation of the muscles, and the result was the reverse of that obtained by Mr. Earle.—See Transactions of British Association, 1834.

* Loc. cit. p. 125.

nerves, when experiment shews that nerves cannot excite these movements."

IV. In regard to the laws, by which the vital powers of contractile parts may be regulated, we have probably much to learn; but three sets of facts have been observed, which may at present be regarded as general laws in this department of physiology.

1. Notwithstanding what has been said of the contractility of muscles being independent of any influence continually flowing to them from the brain or spinal cord, it is well ascertained that in a living and entire animal, where all the functions of the body are, for wise and important purposes, made liable to change, from changes in the nervous system, the contractile power of various moving parts is subject to increase or diminution from physical causes acting in these larger masses of the nervous system, just as they are from various acts and affections of Mind, the effects of which may be said to be *imitated* by those physical causes. Thus in the experiments of Le Gallois, of Dr. Wilson Philip, of Flourens, and others, suddenly crushing any large portion, either of the brain or spinal cord, has been found uniformly to depress or even extinguish the power of the heart; the well-known fatal effect often observed from sudden violent injury of the epigastrium in the human body, has been ascribed with probability to the injury of the great semilunar ganglion; and the depression of the heart's action which attends Concussion, and which is the immediate cause of death in the most quickly fatal cases of that kind, is also generally regarded as an impression, made originally on the nervous system, and immediately transmitted to the heart. On the other hand, slighter and more continued physical irritations of the nervous system appeared in many experiments, especially of Dr. Wilson Philip, to augment the irritability of the heart. It is true that, in all these cases, some have supposed the effects of the violence to be on the organs of circulation directly, and not through the intervention of the nerves; but when it is remembered, that some of those injuries, which are the most rapidly fatal to the heart's actions, (such as the pushing of a probe along the spinal canal,) do not necessarily imply any great violence to the body at large; and further, that precisely similar effects on the heart's action (both increase and diminution) often result from mental emotions and passions, which certainly act first on the nervous system, the account which we give of the mode of action of these causes appears to be sufficiently confirmed.

One cause, acting primarily on the nervous system, which seems to have a peculiar depressing effect on the heart's action, is, sudden removal of the pressure to which the brain had previously been subjected. The effect of this on the heart has been repeatedly seen in surgical operations; and this seems to be an essential part of the pathology of several cases of syncope, particularly of that which results, either from bloodletting in the erect posture, or from tapping in ascites.

It is very remarkable that the heart, which is so strictly an involuntary muscle, and so little liable to excitation by stimuli applied to its nerves, is much more liable than the voluntary muscles both to sudden increase and to diminution, or even total loss, of vital power from such causes as we have now considered. But a little reflection will shew, that the direct stimulation of a muscle, and the increase or diminution of its irritability, are perfectly distinct cases. And we may approximate, at least, to an explanation of the peculiar liability of the heart (and probably of other involuntary muscles) to the influence of such causes acting through the nervous system, as augment or depress the vital power, when we remember two facts: 1. that the causes which act in this way are very generally such as are applied to *large portions* of the brain or spinal cord;* and 2. that the arrangements of the ganglionic nerves are such as to place the heart and other organs supplied from the ganglia, in connexion with the *whole extent* of the cerebro-spinal axis, and hardly with any individual part of it more than another.

2. There are various external agents, by the application of which the vital power of contractile parts, and especially of the heart,—the main agent in the circulation,—may be altered or even destroyed. It is increased, not only by moderate increase of the Temperature in which living parts are kept, and of the quantity of arterial blood sent to them, but also by Electricity applied in a low degree of intensity, and by various articles of diet and medicinal agents, such as the various preparations of Alcohol; and it is diminished, or even suddenly extinguished often by the same agents applied in excess, (as in the case of Lightning when most rapidly fatal,) and still more remarkably by certain Poisons, such as the upas antiar, tobacco, digitalis, arsenic, and hydrocyanic acid. It is still doubtful through what medium these poisons act on the vital power of the heart; but it is certain that the effect which they produce on that power is the immediate cause of the death resulting from them.†

In cases of the most sudden death produced by such causes acting in the utmost intensity, the contractile power in the voluntary muscles, as well as in the heart, has been found to be very much diminished or even nearly extinguished; and it is very important to observe, that in such cases the property of coagulation in the blood is likewise lost; which seems clearly to indicate (what various other facts confirm) that this change in the blood is dependent on the existence in that fluid of a certain degree of the same vital properties, to which we give the name of Contractility as existing in the solids.

3. The contractile power of living parts is liable to much alteration from the degree in

* See Dr. Wilson Philip's Experimental Inquiries, &c. ch. ii. and iv.

† The terms Stimulant and Sedative are applied most correctly to those agents which thus exalt or depress the vital actions of the circulating system.

which it is itself exercised. The immediate effect of frequently repeated stimulation of a voluntary muscle, whether by physical or mental stimuli, in a living or newly killed animal, is gradual diminution or ultimate extinction, or what is usually called Exhaustion of its Irritability; which is gradually restored when the stimulation is discontinued and the muscle is at rest.

But the theoretical conclusions which have been drawn from this fact have greatly exceeded the legitimate inferences. It is by no means clear that such increased action of *involuntary* muscles, as results from causes of the kinds just mentioned, which exalt or increase their contractile power, is necessarily followed by any corresponding depression. On the contrary, in the case of violent exercise, in many instances of mental agitation and excitement, and in the course of certain febrile and inflammatory diseases, we see the heart's action greatly and permanently increased, without evidence of any subsequent loss of power which can reasonably be ascribed merely to the circumstance of increased action.

It is true that the effect of many stimulating substances, such as alcohol, is first to excite, and after a time to weaken or depress, the actions of the heart and circulating system; but as we know that an equal or greater degree of excitement from exercise, from exciting passions of mind, or from inflammatory disease, may exist without producing any such subsequent depression, we ought to regard the loss of power which follows the excessive use of such substances, as an ulterior effect of these substances themselves, rather than as the result of the mere circumstance of previous increased action.* Although, therefore, we consider all exertions of the irritability of muscles as necessarily implying intervals of relaxation, and are aware of the exhaustion of irritability by *excessive stimulation*, yet we do not see that the operation of those agents which *augment the vital power*, particularly of the involuntary muscles, is necessarily followed by a corresponding loss of power.

Further, it has been often alleged that the vital power of Irritability is not only expended or exhausted by excessive action, but likewise increased or *accumulated* by rest. But there is no evidence whatever that rest does more than merely restore the power that had been lost by previous exertion. A muscle or set of muscles which has been weakened by excessive excitement, and regained its power by rest, may remain quiescent for an indefinite time thereafter, and will not only not continue to gain power, but will gradually lose, after a time, that which it had previously possessed. The idea of the accumulation of Irritability by long-continued inaction has been thought to be supported by the fact, that the stimulating effect of Heat on all vital action, is greatest when it is applied after long-continued Cold. But this seems manifestly to be owing to the principle that the stimulating effect of heat on vital action is proportioned, not merely to the temperature that may be applied, but chiefly to the *degree of change* of temperature undergone in a given time; of which point many illustrations might be given, and which necessarily implies that the effect of Heat must be much increased by its being applied after Cold.

Another law, which may be deduced from observation of repeated exertion of living contractile parts, is of great importance both in physiology and pathology; viz. that the *ultimate* effect of such repeated exertion, with sufficient intervals of repose, is to *augment* both the bulk and strength of muscular fibres, and facilitate the subsequent excitation of vital action, whether in voluntary or involuntary muscles. This is seen in the state of hypertrophy of the muscular fibres of the arms of labourers, of the legs of dancers,—of the heart, in those who have disease of the valves of the aorta,—of the bladder, in those who have disease of the prostate gland or stricture of the urethra; and is in fact only a part of a more general law,—that the habitual exertion (within limits consistent with health) of all vital powers, is naturally attended with an increased flow of blood to the organs exerting those powers, and with an increase of their nutrition. And the counterpart of this is seen in the very slow and gradual, but ultimately extreme diminution, not only of the vital properties, but of the bulk and characteristic appearance, of muscular parts which have been, from any cause, kept very long in a state of absolute inaction. According to the observation of Andral, the structure of muscles may in these circumstances be so altered, that they become ultimately hardly distinguishable from cellular texture. The act of Nutrition, and therefore the organization of muscular fibres, as well as of other living parts, is manifestly intended by nature to be, in a certain degree, dependent on the exertion of their own vital power; and one effect of that exercise of vital power is to solicit or *attract* the living fluid to the part concerned in it, in a manner which the researches of physiologists have not yet satisfactorily elucidated.

(W. P. Alison.)

* See Gregory's Conspectus, art. De Remediis Stimulantibus.

CRANIUM (in anatomy) Gr. κρανιον; Fr. *Crane;* Germ. *Hirnschadel;* Ital. *Cranio.*

The cranium is the protective investment of the brain, on which it is moulded, and the form of which, in warm-blooded animals, it represents. It also incloses and protects the organ of hearing.

In cold-blooded animals there is not this adjustment of the surfaces of the brain and its case; but, although in them the parietes of the cranium are expanded beyond the limits of the brain,* the principle of formation is neverthe-

* Thus, according to Desmoulins the area of a vertical section of the brain in the European tortoise is nearly one-third less than the area of the cranial cavity; and in Fishes, whether osseous or cartilaginous, the disproportion is constantly still greater.—Ed.

less the same; and a glance at the several classes of vertebrated animals will demonstrate that security for the brain is the grand aim of the contrivance, and that the modification it sustains in the case of Fishes and Reptiles is for the purpose of carrying into effect some additional design.

Considering the cranium as a capsule for the brain, its form is necessarily determined by the extent to which that organ is developed in the several classes of animals; while, at the same time, the nature of its organization is in harmonious correspondence with their habits, and with the external circumstances by which they are surrounded. By pursuing this inquiry from the lowest to the highest animals, it will be perceived that, as respects both form and structure, additions are made in proportion as the endowments are of a more and more exalted character; and further, that these successive changes of structure are the changes which the human skull itself experiences in its progress from a fœtal to an adult condition

The rudimentary part of the most elaborate cranium is a sac consisting of two membranes and an intervening gelatinous fluid; in the next step of the formative process, this gelatinous fluid gives place to cartilage. A deposition of earthy matter in this cartilaginous nidus gives it firmness, but breaks up the sac into isolated ununited patches. These isolated patches coalesce in definite numbers, and thus establish a secondary and less numerous division of ununited parts; these, in their turn, approach and combine with each other, forming a solid case of bone; and lastly, this solid case resolves itself into two tables of different structure, and a still further differing connecting medium. In each and all of these states through which the crania of the Mammalia pass there is presented to us a type of the skull in some lower animal.

In Fishes the cranium is little more than a tubular continuation of the spine through the head to contain a similar prolongation of the medulla spinalis. These, however, are not in contact. A mass of reticulated membrane, holding in its cells a gelatinous fluid, forms the real superior investment of the brain; while the superjacent parietes are designed to afford an extensive origin to the muscles of the body; and as these muscles increase, so does the surface of their attachment. For this purpose it is that the ossific deposits remain ununited, that, by being simply in juxtaposition, or at most overlapping each other, they may unfold themselves, and thereby admit of the head being at all times in proportion to the rest of the body.

In Reptiles the skull is still further developed. It is charged more with earthy than with animal matter; and this being loosely distributed, tough spongy bones are the result. The tardiness of their circulation does not favour the combination of the individual portions, and the bones are therefore for the most part loose, although some of them unite by a species of anchylosis in the direction in which defence is required.

In Birds the character both of form and structure is greatly changed; light, fragile, and compact, it is (by reason of the high state of vitality which prevails) so rapidly and completely ossified over its entire surface as to afford no evidence, or but a very slight one, of its original subdivision. In conformity with the development of the brain, it extends itself backwards, to each side, and upwards as well as forwards, thus constituting a considerable portion of the entire head.

In Mammiferous animals the skull is more compact than that of Reptiles and more diffuse than that of Birds. Its elementary portions unite so as to form a determinate number of bones which are either dovetailed together by the interlacement of crooked processes with which their edges are liberally studded, or flow into each other so as to exhibit no trace of their junction. Its structure is made up of two osseous lamellæ, called an inner and an outer table, which are united by an areolar ossific tissue, termed *diploë*, that adds greatly to the defensive properties of the skull.

The Cranium (in human anatomy) is a hollow bone of an ovoid figure; elongated from behind forwards; narrower before than behind; compressed on the anterior part of its sides; surmounting the face and spine, and projecting considerably beyond the latter. It contains in its parietes the organs of hearing, and contributes to form the orbits, the nostrils, and the face.

The dome-like upper portion is termed the *calvaria*, and the lower part is the *base*. The former presents the *synciput* in front, the *occiput* behind, the *vertex* or *bregma*, (βρεχμα, from βρεχω, *irrigo*,) above, and the *temples* on the sides.

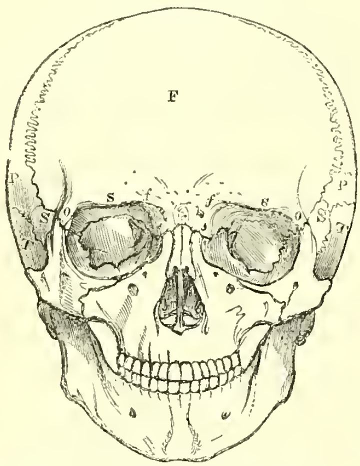
Placed at the summit of the body and destined to contain the brain, the skull is pierced at its base by numerous foramina for the transmission, 1st, of the nerves which establish the communication between the brain and other organs; and 2dly, of the vessels which supply the brain and its membranes.

From the inferior surface of the cranium, between its anterior and middle thirds, there descend two columns which limit posteriorly the boundaries of the face; so that it is anteriorly to these columns that it contributes to form the orbits and the nose, and consequently there the bones which enter into the composition of the face are fixed to it. Hence the surface of that part is very irregular, presenting, in addition to the foramina, depressions and elevations, sulci and processes indicative of the articulation of bones and the lodgement of other organs. Posteriorly, between its middle and posterior thirds, the base of the cranium overtops the spine, and a great opening there establishes the continuity of the vertebral canal with the interior of the skull; and the muscles which move the head and maintain its equipoise being attached around, but especially behind this opening, the skull is strongly marked in that direction. The intermediate space or middle third is above the pharynx, offering, centrally, a plain surface to form the roof of that cavity, and, laterally, rough surfaces and processes for the attachment of muscles concerned in deglutition, also some of the foramina already referred to, for the transmission of the vessels and nerves of the throat to and from the interior of the skull, as well as the surfaces on which the lower jaw moves.

The upper surface of the base conforming to the base of the brain, there are larger depressions on it for the anterior and middle lobes; a deep pit or cavity for the cerebellum, and in the centre a broad sulcus, which glides into that pit, for the medulla oblongata, as well as strong ridges and processes to afford attachment to the membranous partitions which severally exist between the cerebrum and cerebellum, the hemispheres of the former and the lobes of the latter organ.

The bones into which the cranium is separable or of which it is immediately formed, are eight, viz. the *sphenoid*, the *frontal*, the *ethmoid*, the *occipital*, the two *temporal*, and the two *parietal*. The first named bone is so placed as to be in connexion with all the others, and to have them grouped around it; so that the frontal (F, *fig.* 370) and ethmoid are in its front, the

Fig. 370.



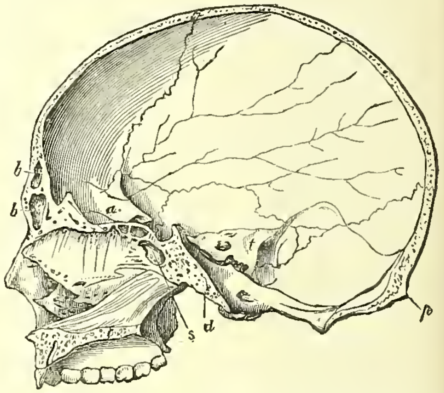
occipital (O, *fig.* 372) is behind it, the two temporal (T, *fig.* 370) are on its sides, and the two parietal (P, *fig.* 370) are above it.

The *sphenoid bone* (from σφην, *cuneus*, *os sphenoidale;* Germ. *Sphenoidal-knochen*, *Keilknochen)* comprehends the quadrilateral mass which forms the centre of the frame-work, the anterior ribs which support the frontal and partly the lateral domes, and the depending pillars which form the boundaries of the face; it extends to each temple, is behind and in part forms the orbits and the nose, and is also behind but in close connexion with the bones of the face.

The central portion is called *the body*, and the diverging processes are named alæ majores and alæ minores.

The *body* is of a quadrilateral figure, hollow and divided by a partition into two chambers (the *sphenoidal* cells, *s*, *fig.* 371), which open through the medium of the posterior ethmoidal cells into the superior meatus of the nose. *On its upper surface* is a deep depression *(ephippium, sella turcica, fossa pituitaris)* for the lodgement of the pituitary gland. The posterior border of this depression presents a crest, the corners of which are slightly tumid, *(posterior ephippial*, or *clinoid processes,)* for the attachment of the tentorium, and this crest is prolonged downwards and backwards under the name of the *basilar process*, to join the process of the same name of the occipital bone; on each side there is a depression *(sulcus caroticus)* for the reception of the internal carotid artery, and which also marks the situation of the cavernous sinus. *On its under surface* may be seen, on the median line, the *processus azygos (rostrum)*, which is wedged into the base of the vomer, and on each side of it a line indicating the articulation of the two plates of which the vomer is formed. Still more outwardly there is a groove which is converted into a canal by the application against it of the inferior orbitary or sphenoidal process of the palatine bone.

Fig. 371.



The anterior surface exhibits the openings of the sphenoidal cells, having, between them, and apparently a continuation of their septum, a prominent ridge which articulates with the vertical plate of the ethmoid, and, below them, the triangular curved processes denominated the *turbinated processes* of the sphenoid bone. Externally to these foramina and turbinated processes on each side is a rough line for the articulation, in its two superior thirds, of the orbital plate of the ethmoid, and, in its inferior third, of the orbitar process of the palatine bone. To the outer side of this rough line is a smooth surface which contributes to the formation of the orbit.

The posterior surface is rough, quadrilateral, and at an early age becomes indissolubly united to the basilar process of the occipital bone (*d*, *fig.* 371); for which reason Sœmmerring and Meckel have regarded as one, the occipital and sphenoid bones, and as such have described it under the name of *os basilare*.

This surface is bounded superiorly by the basilar process before mentioned, which is placed with such a degree of obliquity, that it may be questioned whether it be on the posterior or superior surface of the body of the bone. It is smooth, slightly concave, and on its edges may often be seen the commencement of the *sulci basilares* for the lodgement of the basilar sinuses.

The *alæ majores* are those large curved processes, which, stretching outwards, forwards, and upwards, contribute to form the middle fossæ of the skull, the orbits, and the temples.

The *upper surface* of each ala, that which in part forms the middle fossa of the base of the skull, is concave from side to side, and still more so from behind forwards. On it are seen (though not so distinctly) the digital impressions which mark the lodgement of convolutions of the brain on the cerebral surface of the other bones of the skull. Close to the spot where it departs from the body of the bone there is a sulcus directed forwards, and terminating in a round hole *(foramen rotundum)* for the exit of the superior maxillary branch of the par trigeminum or fifth pair of nerves. More outwardly, and behind the plane of the posterior edge of the body of the bone, is a large oval opening *(foramen ovale)*, directed downwards and slightly outwards for the transmission of the inferior maxillary branch of the par trigeminum and the entrance of the ascending pharyngeal artery, which then becomes a meningeal vessel. Behind this foramen is another (the *foramen spinale)*, which is very small, and affords entrance to the middle meningeal artery.

On the *inferior surface* are seen the *pterygoid processes* descending from the great wing where it joins the body of the bone, to afford a resisting surface against which the bones of the face may be grouped. Anterior to these processes is the termination of the *foramen rotundum*, the opening of which is directed somewhat outwards, and from which there passes, outwards and upwards, a groove *(sulcus temporalis)* for a deep temporal branch of the superior maxillary nerve. Behind the pterygoid processes, and extending from the base of the internal to the extremity of the wing, is the *sulcus Eustachianus*, which lodges part of the Eustachian tube, and on the outer side of this sulcus are seen successively the foramen ovale and the foramen spinale. Immediately behind the latter opening, and overhanging the Eustachian tube, is the styloid process, to which the internal lateral ligament of the lower jaw is attached. On the outer side of the pterygoid processes is a plain surface forming part of the zygomatic fossa, and bounded externally by a crest, which marks the division between the zygomatic and the temporal fossæ, and which intervenes between the superior attachment of the external pterygoid and the inferior attachment of the temporal muscles.

The pterygoid processes consist of two plates, with a triangular separation inferiorly, and they are called the *external* and the *internal pterygoid processes* or *plates*. The *external* is broader, thinner, and is directed more outwardly than the internal; its outer surface, which also looks a little forwards, gives attachment to the external pterygoid, its inner to the internal pterygoid muscles. The *internal* is nearly vertical; it is pierced longitudinally at its base by the *canalis Vidianus* for the passage of the vessel and nerve which bear that name; at its inferior extremity there is a hook (the *hamular process)*, which acts as a pulley for the tensor palati muscle, the attachment of which to the outer side of the internal pterygoid process is shewn by a sulcus which is most evident at the base *(fossa navicularis)*; to its anterior edge is applied a thin plate of the palatine bone, thus separating it from the superior maxillary, and to its posterior edge is affixed the aponeurotic origin of the superior constrictor of the pharynx. The concavity between the two processes is the *fossa pterygoidea* which is occupied by the internal pterygoid muscle, and the notch at the lower part (the *hiatus palatinus)* is filled up by the pterygoid process of the palatine bone.

The *external surface* of each ala is continuous with the inferior; it is concave from before to behind, and convex from above downwards; it contributes to the formation of the temporal fossa, and the continuation of the sulcus temporalis is evident at its anterior part (S, *fig.* 373).

The *anterior surface* forms the major part of the external wall of the orbit, is oblong, directed forwards and inwards, and is narrower at its extremities than in its middle.

The *superior border* of the great wing separates the orbital from the cerebral surface; it presents a sharp smooth edge on its inner half, and a rough irregular surface on its outer half; it is convex, and its convexity is directed upwards, forwards, and inwards. The sharp internal half concurs with the alæ minores to form the sphenoidal fissure, which will be described with those processes. The external rough half becomes broader as it passes outwards, so as to produce a triangular indented surface, the outer edge of which is prolonged at the expense of the inner table in such a manner that it overlaps the frontal bone which is affixed on it, and this prolongation is continued without the indented surface, so as to grasp the anterior inferior spinous process of the parietal bone.

The *external border* is nearly the reverse of the former. It is concave, and looks outwards and backwards, and it is articulated in its entire extent to the squamous portion of the temporal bone, by which it is overlapped in its anterior third, and receiving and supporting it in its two posterior thirds; the former at the expense of its outer table, the latter at that of the internal.

The *posterior border* is applied against the outer side of the petrous portion of the temporal bone, and extends from the body of the sphenoid to the posterior extremity of the external border. The junction of these two borders forms the *spinous process*, which is received into the angle of the petrous and squamous portions of the temporal bone. The laxator tympani muscle arises from this process, and the *styloid process* before described descends from it. The angle which exists where this border departs from the body, in part forms the *foramen lacerum anterius*, an opening which, in the recent skull, is closed by cartilage.

The *anterior border* consists of two portions which join with each other at an angle. Of these the upper is indented, separates the orbital from the temporal surface, and articulates with the malar bone. The inferior portion is smooth, and forms with the palatine and superior maxillary bone, the *fissura lacera orbitalis inferior*.

The *alæ minores* are on the upper and anterior part of the body of the bone; they extend outwards over the superior borders of the greater wings, and, gradually tapering, they at last end in a point.

The upper surface of each ala minor is smooth, and partly forms the anterior fossæ of the skull. The *processus ethmoidalis* is a thin lamina somewhat triangular in form, prolonged forwards on the median line to articulate with the cribriform plate of the ethmoid bone. Passing backwards from this process, there is a slightly elevated line separating the depressions which on each side receive the olfactory nerves, and terminated posteriorly by a tubercle (*processus olivaris*) marking the decussation of the optic nerves, and having upon it a transverse depression for the lodgement of their commissure. This depression terminates on each side in the *foramen opticum* for the passage of the optic nerve and the ophthalmic artery, in such a manner that the lesser ala appears to arise by two roots, one above and the other below the foramen. From the sides of the processus ethmoidalis there pass the two *transverse spinous processes*, being the anterior serrated margins of the wings; they are articulated to the orbitar processes of the frontal bones, and sometimes join by their extremities the great wings; thereby, in such a case, converting the superior orbital fissure into a foramen without the aid of the frontal bone. The posterior margins of the alæ minores are smooth and less sharp than the anterior; they are prolonged backwards and inwards, so as to form on each side a short and thick triangular process, the apex being directed backwards, called the *anterior ephippial (anterior clinoid)* process, to which the cornua of the lunated margin of the tentorium are attached.

The inferior surface of each ala minor forms the posterior part of the orbit. On it is seen the opening of the optic foramen, and underneath it, between the smaller and the greater wings, the *fissura lacera orbitalis superior*. This fissure is completed into a foramen by the articulation of the frontal bone to the sphenoid, when it appears as an elongated triangular opening directed from below upwards and from within outwards. Thus is formed the *foramen lacerum orbitale superius*, which allows to emerge from the skull the third, fourth, the ophthalmic division of the fifth, and the sixth pair of nerves, and to enter from the orbit the ophthalmic veins.

The articulations then of this bone are, to the ethmoid, by the ethmoidal process and the fore part of the body; to the frontal, by the transverse spinous processes, and the summits of the great wing; to the parietal, by the tips; to the temporal, by the external and posterior borders, and to the malar, by the anterior borders of the same wings; to the occipital, by the basilar process; to the palatine, by the pterygoid processes and adjacent part of the body; and to the vomer, by the azygos process.

The sphenoid bone is developed by numerous points of ossification, some of which coalesce before the others appear; and during the period of intra-uterine life the union of these parts is so rapid, that, at birth, the bone consists but of three parts, one central, comprehending the body and smaller wings, and two lateral, each involving a great wing and its corresponding pterygoid processes.

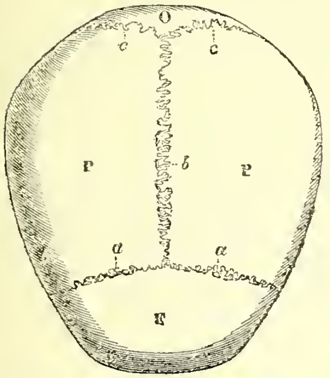
So early as the third month there appear six points of ossification, two in the great wings, two in the internal pterygoid processes, and two in the smaller wings. During the fourth, fifth, and sixth months six points are established in the body, one on each side the median line, afterwards another between these and the corresponding greater wing, and ultimately another between the optic foramen and those already existing. During the sixth month also a deposit appears between the optic foramen and the olivary process. In the course of the seventh month the six points of ossification in the body run into each other; in the next month a coalition takes place between those in the pterygoid processes and those in the greater wings, and shortly afterwards a similar union occurs between the point in the small wing and that near the optic foramen. Towards the termination of the ninth month the two smaller wings are associated together, which then become attached to the already formed body, and thus constitute at birth the three pieces which exist at that epoch.

In the early period of extra-uterine life these three portions unite into one, the great wings acquire a more determined curvature than they at first possessed, the pterygoid processes lose their striated appearance, and exhibit more completely their fossa; but it is not until after the lapse of years that the absorbing process, which, commeneing in the centre of the body, developes the sinuses, is terminated, so that during childhood there is not only an absence of these sinuses, but of the openings leading from them and of the turbinated processes which are fixed to their front.

2. The *frontal bone (os frontis, coronæ*; Germ. *das Stirnbein,)* (F, *fig.* 370, 373,) is situated at the anterior part of the cranium, forming part of the vault and part of the base, but considerably more of the former than it does of the latter. It comprises the two anterior ovoidal domes and the anterior portion of the longitudinal eurved rib of the general frame-

work, which will be afterwards more fully explained. The convexity of these domes is turned outwards and forwards in such manner that the circumference may abut against the longitudinal rib internally; and, behind against the anterior rib in the base and a portion of the circumference of the lateral dome in the vault. That portion which is in the base is, as it were, pressed upwards to increase the space of the orbit, but not so much so as, at first sight, might appear; for on the external surface of the junction of the two portions there is an extraordinary development of the bone, which projecting over the face destroys the uniformity of surface and causes the orbitar portion to appear more elevated than it is in reality, and even to pass backwards at right angles with the other.

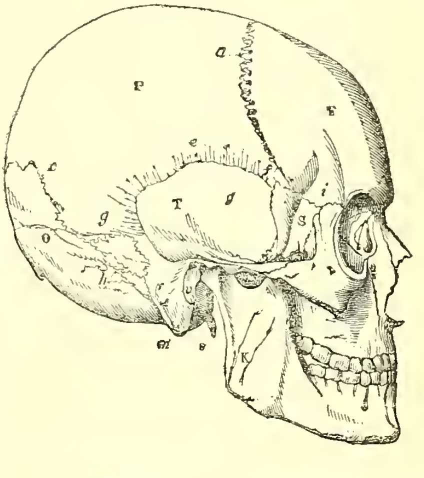
Fig. 372.



The *external surface* of the *frontal portion* in its upper two-thirds is smooth, of an equable convexity and directed backwards; its inferior third is more vertical, and its convexity is interrupted by prominences. On the median line it exhibits evidence of its original division into two parts, and this generally by a slight ridge, although in some instances there is a linear depression of equal indistinctness. This line is terminated by the *nasal prominence*, which has immediately above it a smooth triangular surface *(glabella)*, and below it a rough notch for the articulation of the nasal and superior maxillary bones. From the centre of this notch there is a projection *(processus nasalis)*, on the fore part of which are fixed the nasal bones, and to its back part, which is grooved, the ethmoid bone is applied.

On either side of the median line there is, at about the distance of an inch where the middle joins with the lowest third of the bone, the *frontal eminence (eminentia frontalis, processus primi genii)*, which marks the centre of ossification, and the prominence of which is inversely as to the age of the subject. Below this eminence, bounding the *glabella*, and inclining downwards and inwards towards the nasal prominence (with which, in fact, it is ultimately confounded), is a pyramidal protuberance, varying very much in distinctness in different individuals, *(processus frontalis,)* more evident below than above, and indicating the situation of the *frontal sinus*. There is a slight depression underneath and to the outer side of this process, and, finally, the *superciliary ridge* terminates the frontal portion of the bone. This ridge is more prominent at its outer than at its inner side; its extreme points are called *external* and *internal angular processes*, to the former of which the malar bone is articulated, to the latter the os unguis; at the junction of its inner and middle thirds there is a *hole (foramen supra orbitarium)*, or otherwise a *notch*, for the passage of the frontal branch of the ophthalmic vessels and of the ophthalmic division of the fifth pair of nerves. Behind the external angular process there is a *depression (fossa temporalis)* which forms part of the *temporal fossa*; a part of the temporal muscle is attached to it, and it is bounded above by a *line (linea temporalis)* which is continuous with the outer margin of the external angular process, and to which is attached the temporal aponeurosis.

Fig. 373.



The *posterior* or *cerebral surface* of the frontal bone is concave, is marked by depressions which correspond with the convolutions of the brain, and by sulci for the lodgement of the arteries of the dura mater, and is continuous inferiorly with the orbitar portion; corresponding to the eminentiæ frontales there are two depressions, and on the median line there is a sulcus *(sulcus longitudinalis)* for the reception of the longitudinal sinus, on the edges of which sulcus may sometimes be seen the fossæ Pacchionii for the glands of the same name. This sulcus as it descends is generally replaced by a dense crest, which projects considerably into the cavity of the cranium; to it and to the edges of the sulcus, the falx cerebri is attached; and at its lowest point it is bifid, so that, by its being applied against a similar bifurcation of the processus cristatus of the ethmoid bone, it contributes to form the *foramen cæcum*.

The *orbitar portion* by its upper surface supports the anterior lobes of the brain, and its under surface forms the root of the orbits. It is divided into two processes by a longitudinal notch, which corresponds to the roof of the nose.

The *orbitar process* of either side is convex in both directions on its *upper surface*, and the mammillary eminences and digital impressions formed by the intergyral spaces and convolutions of the brain are of a decided character. On its *under surface* it is concave and triangular, the base being directed forwards; at its anterior and outer part there is a *fossa (fossa lachrymalis)* for the lachrymal gland, and which is overhung by the external orbitar process; at its anterior and inner part, near to the internal orbitar process, and between it and the foramen supra-orbitarium, there is a small *pit (fossa trochlearis)* to which is fixed the cartilaginous pulley in which plays the tendon of the superior oblique muscle of the eye; at the middle of its inner edge there is a *notch*, which, applied to a similar notch of the ethmoid bone, constitutes the *foramen orbitarium internum anticum*, through which pass the ethmoidal twig of the ophthalmic branch of the fifth pair of nerves, and the anterior ethmoidal branch of the ophthalmic artery; and a little behind this there is another notch, which by a like contrivance forms a hole (the *foramen orbitarium internum posticum)* for the passage of the posterior ethmoidal branch of the ophthalmic artery and corresponding vein.

The notch which is between the orbitar processes is the *hiatus ethmoidalis (incisura ethmoidalis)*, and in the cranium it is filled up by the cribriform plate of the ethmoid bone. Its longitudinal is twice the length of its transverse diameter; anteriorly, it is bounded by the notch which, in part, forms the foramen cæcum and the posterior surface of the nasal process; posteriorly, it is open; and its sides are bounded by the commutual edges of the orbitar processes, the tables of which are separated in such a manner as to communicate with the ethmoidal cells and close them at the upper part, and at the anterior part of the notch to communicate also with the frontal sinuses.

The frontal sinus is formed by the separation of the two tables of which the bone is composed, and by the absorption of the diploë; they are usually separated by a septum, and they communicate on each side with the middle meatus of the nose in the manner indicated above.

The posterior and upper border of the bone as far down as the posterior extremity of the inferior margin of the fossa temporalis, is articulated to the parietal bones; and it will be remarked that rather more than the middle third of it advances upon and secures those bones at the expense of their outer table, while the inferior portions of it are in their turn grasped by each parietal bone respectively, the outer table of the latter advancing, at this part, upon the inner table of the former.

Behind the external angular process, between the temporal fossa on the one hand and the orbitar process on the other, there is a triangular rough surface which is implanted on a similarly-disposed surface of the great wing of the sphenoid bone. The posterior margin of this surface is in apposition with the edge of the thin extremity of the small wing of the sphenoid, to which also is articulated the remaining portion of the posterior border of the orbitar process; but with this difference, that, while in the former instance the edges are plain and simply applied to each other, in the latter the margins are denticulated, the sphenoid overlapping the frontal so as to render the roof of the orbit secure.

Thus the frontal bone articulates by the posterior borders of its two portions, with the parietal and sphenoid; by the inner edges of its orbitar processes, with the ethmoid; by its nasal process, with the nasal; by its internal angular process, with the lachrymal; by the surface between the nasal and internal angular processes, with the superior maxillary; and by its external angular process, with the malar bones.

This bone in the fœtus, and for nearly two years after birth, consists of two pieces, the first deposit in each being at the prominence already indicated. From this point the ossific matter radiates, and approaching that from the opposite side, the two combine so as to form on the median line a suture which is speedily effaced. Nevertheless it occasionally happens that complete union does not take place, and then the suture persists through life.

The *ethmoid bone* (ηθμοειδης, ηθμος, *cribrum, os ethmoideum;* Germ. *Ethmoidal-knochen)* completes that portion of the base of the cranium, anterior to the sphenoid, which is not supplied by the frontal. It is however devoted less to the skull than to the face, with many of the bones of which it is connected; and it contributes greatly to form the nostrils and their septum, as well as both of the orbits.

As an element of the cranium it is very simple, being merely a plate connecting the two orbitar processes of the frontal bone, and having on its median line a ridge, which joins the frontal spine before, to the body of the sphenoid bone behind. This plate is the *cribriform plate* or *process;* it is notched posteriorly where it receives the ethmoidal process of the sphenoid bone, the apex of which process is applied to the posterior extremity of the central ridge. Advancing forwards, this ridge quickly springs upwards as a pyramidal process (the *crista galli*, or *processus cristatus)*, to which the falx cerebri is attached; its posterior edge is long and oblique, its anterior is shorter, more vertical, and it terminates inferiorly in two slightly divergent plates, so as to form by their articulation with the frontal bone the *foramen cæcum*. On each side of the crista galli, more especially towards the forepart, the cribriform plate is channelled for the reception of the olfactory nerves, and each channel is perforated by numerous foramina for the transmission of the ramifications of the olfactory nerves *(foramina cribrosa)*. These openings are variable in their number, and differ from each other in their size and modes of termination; those nearest the crista galli are the largest, and of them one or two of the anterior ones are very considerable; the smallest are situated on the outer edge of the cribriform plate, and both of these sets are the orifices of canals which terminate, the former about the root and upon the sides of the septum, the latter on the outer wall of the nose; those which are intermediate and in the centre of the channel, are complete foramina, and open on the opposite surface of the plate. Immediately in front of the inner set of foramina, there is, between the crista galli and cribriform plate, a fissure which gives passage to the ethmoidal nerve and vessels.

From the under surface of the cribriform plate and at right angles with it, there descend, on the median line, the *nasal lamella*, and, on each side, a cellular mass which partly forms the outer wall of the nostril and the inner wall of the orbit.

The nasal lamella, or vertical plate, forms the upper portion of the *septum narium;* it is immediately underneath the crista galli, and becomes gradually thinner as it descends; its anterior border is rough, thicker above than below, and articulates, first, with the nasal process of the frontal bone, and, secondly, with the nasal bones themselves; its posterior border is also rough and is articulated to the crest on the fore part of the sphenoid bone; its inferior border is, in its posterior half, thin and inclined downwards and forwards to be articulated to the vomer, and, in its anterior half, somewhat thicker and rougher, and inclined downwards and backwards to be articulated with the triangular cartilage of the nose; its sides are plain, and exhibit sulci which are continuous with the foramina that open on its root.

On each side of this lamella and between it and the lateral masses there is a space which is encroached upon in the middle more than it is above or below, and a portion of the cribriform plate forms its roof.

The lateral masses are delicate in their structure and complicated in their arrangement. Each consists of a number of cells *(cellulæ ethmoidales)*, which are divided by a partition into an anterior and a posterior set, with the former of which the frontal sinus communicates, and with the latter the sphenoidal. The *outer surface* of each lateral mass is compact and smooth, and constitutes the greater portion of the inner wall of the orbit. This is the *orbitar process* or *os planum*, which articulates above with the frontal bone, below with the superior maxillary and palate bones, behind with the sphenoid, and in front with the lachrymal. On its upper border are seen the two notches which assist the frontal in forming the anterior and posterior orbital foramina. The inner surface of this cellular mass, that which looks towards the nasal lamella, is rendered irregular by two curved processes (the *superior* and *middle turbinated processes)*, of which the upper one is smaller, delicate, regular in its curve, and is seen only on the posterior half of the wall; the other is larger, more spongy, and extends the entire length of the wall. Both of them are convex on the side next the cavity of the nostril, and concave on that which looks towards the cells; but the inferior is also at its lower edge again curled in such a manner as to offer a convexity on both of its surfaces. Between the two turbinated processes there is a triangular space (the *superior meatus)* the apex of which is directed forwards, and in which there is an opening communicating with the posterior ethmoidal cells. Underneath the middle turbinated process, and bounded by its concavity on the one hand and the cells on the other, is the *middle meatus;* into which open the anterior ethmoidal cells, and the tubular communication with the frontal sinus, called *infundibulum*.

The connexions of this bone are, behind to the sphenoid; in front to the frontal and nasal bones; laterally by its upper borders to the orbitar processes of the frontal, by its under borders to the same-named processes of the superior maxillary and palate bones, and by its anterior border to the lachrymal; by the under edge of its middle vertical plate to the vomer and triangular cartilage; and by the anterior extremity of the outer surface of the middle turbinated process to the inferior turbinated bone.

The ethmoid is the most tardy in its development of all the bones of the cranium. The lateral masses exhibit each of them an ossific deposit about the middle period of intra-uterine life, but neither the cells nor turbinated processes are much developed at birth, at which time also the central portion is cartilaginous. The ossification of this part proceeds from above downwards, so that the crista galli is completely formed while the lower part of the nasal lamella is yet cartilaginous. During infancy the cribriform plate becomes narrower, curved, and as it were compressed; the nasal lamella advances forwards; and the spaces between the septum and outer walls are considerably increased.

The *occipital bone (os occipitis;* Germ. *Occipital-knochen*, *Hinterhaupts-knochen,)* is situated behind the sphenoid, and forms the posterior part of the base of the cranium and the contiguous projection of the occiput. Its figure is that of a lozenge with its anterior angle truncated, and is so curved as to be generally concave on one surface and convex on the other. The inferior and anterior half of it is situated between the two temporal bones; the superior and posterior half is between the posterior margins of the two parietal.

At its anterior part it is pierced by a large elliptical foramen (the *foramen magnum)*, through which there pass, from the skull, the medulla spinalis and its membranes, the sinus venosus and the spinal arteries; and, into the skull, the vertebral arteries, the posterior meningeal arteries, and the nervus accessorius.

On the cerebral surface the *internal crucial* *spine* divides it into four fossæ, the two superior of which are the *fossæ cerebri* for the posterior lobes of the cerebrum, the two inferior, the *fossæ cerebelli*, for the hemispheres of the cerebellum; the former being marked by the convolution of the brain, they are not so smooth as those which lodge the cerebellum. The lower limb of the crucial spine is prominent, and arises by a bifid root from the margin of the foramen magnum; the upper limb is grooved for the reception of the longitudinal sinus, and to its borders the septum cerebri is attached; this groove is mostly directed to one side or the other, and generally to the right; to the lateral limbs the tentorium is fixed, and the grooves which are on them contain the lateral sinuses. At the point where the transverse bisects the vertical portion of the crucial spine, it is very prominent, is called the *internal occipital protuberance*, and marks the situation of the torcular Herophili.

In front of the foramen magnum, ascending obliquely towards the sphenoid bone, and narrowing in its ascent, is the upper surface of the *basilar process*, which is concave from side to side for the lodgement of the pons Varolii and medulla oblongata, and exhibits on each margin a depression (the *sulcus basilaris*) for the basilar or inferior petrosal sinus.

On either side of the foramen magnum is a groove which advances from without inwards, and from behind forwards, and lodges the termination of the lateral sinus. The anterior extremity of this groove turns downwards and forms a large notch (the *fossa jugularis*), which is bounded on the outer side by a strong rough process (the *processus jugularis*), and on the inner side by a smooth oval eminence which is situated between it and the sulcus basilaris, and below which is the orifice of the *foramen condyloideum anticum* for the passage of the motor linguæ nerve.

The external convex surface, in that part which is behind the foramen magnum, is divided into an inferior rough, and a superior smooth, triangular portion. The division between the two is marked by a curved line (the *superior occipital ridge*), which abuts on the petrous masses of the temporal bones, and exhibits in its centre the *tuberose process*, or the *external occipital tubercle*, to which the ligamentum nuchæ is attached. From the ridge next to the tubercle the occipito-frontalis and trapezius muscles arise, and, still more outwardly, the splenius capitis and the sterno-cleido-mastoideus are attached. From the tubercle to the foramen magnum extends a *longitudinal spine*, which is bisected in its middle by a second curved line (the *inferior occipital ridge*), and constitutes, thereby, the *external crucial spine*. On each side of the spine and between the two ridges, there is a considerable rough depression for the attachment of the complexus, and, to the outer side of it, one which is smoother, for the trachelo-mastoideus. Between the inferior ridge and the foramen magnum, there are on either side of the longitudinal spine, indications of the attachment, in succession, of the recti capitis postici minores et majores and of the obliquus capitis superior. On the outer side of this region is the *sulcus occipitalis*, which runs backwards and upwards between the surfaces of attachment of the trachelo-mastoideus and the complexus, and is formed by the occipital artery.

Underneath the anterior half of the margin of the foramen magnum are the *condyloid processes*, two elongated articulating eminences, convex in both directions, wider in the middle than at either end, inclined from above downwards, from behind forwards, and from without inwards, and having their internal edges below the level of the external. On the inner side of each process is a rough surface for the attachment of the odontoid ligament; on the outer side is a ridge (the *processus lateralis*) which ends in the jugular process, and gives insertion to the rectus capitis lateralis; anteriorly is the anterior orifice of the anterior condyloid foramen; and posteriorly there is a depression in which is sometimes seen a foramen (*foramen condyloideum posticum*) through which a vein of the scalp communicates with the terminal portion of the lateral sinus.

In front of the foramen magnum is the under surface of the basilar process, which, by reason of the superior thickness of its anterior extremity, is not so oblique as it appears on its upper surface. There is a slight tubercle on the middle line to which is fixed the middle constrictor of the pharynx, and behind it, on both sides, a transverse line for the superior constrictor, between which and the foramen are depressions caused by the recti capitis antici majores et minores.

The *superior angle* of this bone is applied on the junction of the two parietal, and the serrated borders which extend from it to the lateral angles are articulated to the posterior borders of the same bones. The upper angle itself and more than half of the borders proceeding from it, overlap the parietals, but in the remainder of their extent the latter bones overlap the occipital; in each case the arrangement being the same as that which exists between the parietal and the frontal bones.

From the *lateral angles* to the jugular processes, a rough but not denticulated border articulates it to the posterior border of the mastoid portion of the temporal bone. Immediately in front of the jugular process is the fossa jugularis, which forms, in common with the temporal bone, the *foramen jugulare* or *foramen lacerum posticum in basi cranii*, through which emerge the jugular vein, the pneumo-gastric, glosso-pharyngeal, and spinal accessory nerves. The rest of the border from the fossa jugularis to the anterior angle is in apposition with the petrous portion of the temporal bone, but the quantity of cartilage between them is too large to admit of there being any fixed articulation at this part.

The anterior angle itself is truncated and presents a rough quadrilateral surface, which articulates, and, indeed, consolidates itself, at an early period of life, with the basilar process and body of the sphenoid bone. This union is so complete and so similar to the union which takes place beween the several elements of the bones of the cranium, that Soëmmering and Meckel have described the two as one bone, under the name of *os busilare* or *os spheno-occipitule*.

The connexions of this bone are few and simple, being, in its superior half, with the parietals; in its inferior half, with the temporals; at its anterior extremity, with the sphenoid; and, by its condyles, with the atlas.

At birth this bone is separable into four distinct portions, one being in front, one behind, and one on each side of the foramen magnum, the border of which is, consequently, not then completed. The anterior and two lateral portions are formed by the extension of ossific matter from one point of deposit in each; but that posterior to the foramen is produced from many points, in the number of which anatomists are not agreed. The ossification commences in the lower part, at some distance from the foramen, by one point on each side of the median line; and before they have completely approached each other, two analogous deposits appear in the upper part, which coalesce before the upper and lower pieces are joined. This occurs during the fourth month, at which time the inferior and broad part displays on each side another point of ossification on a level with the spot where the process first commenced; in the fifth month the whole of these are consolidated into one piece. It often happens, however, that other deposits are formed, especially in the upper part; and frequently they refuse to merge into the others, continuing then to be distinct through life as separate small bones having their own serrated margins to articulate with the adjoining structures.

The lateral pieces (those which comprehend the condyles, and lateral and jugular processes) commence their formation about the fourth month; and the anterior piece is the last in the order of development.

The *temporal bone (os temporum;* Germ. *das Schlafenbein.)* One is situated on each side of the sphenoid and lower half of the occipital bone; they complete the base of the cranium and form the inferior part of the sides of the vault.

For the purposes of description it is usually divided into three portions; one, strong and compact, in the base and between the middle and posterior fossæ, the *petrous;* a second, tumid and less dense, behind the ear, the *mastoid;* and a third rising from the former two, thin and scaly, situated in the temple, the *squamous*.

The *petrous portion* is an elongated, pyramidal mass, of which two of the surfaces enter into the formation of the cavity of the cranium, and the third is underneath. It is situated on a line which, if prolonged, would extend from behind the ear to the opposite external angular process of the frontal bone; but it is limited by the body of the sphenoid. It occupies the space between the posterior border of the ala major of the sphenoid and the basilar process of the occipital bone, in the angle of which its free extremity is impacted. In its substance is contained the labyrinth of the ear.

Of the two *surfaces* which are in the cranium, one is superior, the *cerebral;* the other is posterior, the *cerebellur*.

On the *cerebral surface* near its middle, is a smooth, convex, and transverse elevation (the *processus semicircularis)*, produced by the superior semicircular canal of the labyrinth; immediately in front of this is a depression on which the Gasserian ganglion lies; more outwardly and running lengthwise, is a faint sulcus (the *sulcus Vidianus)*, which terminates at a small opening (the *hiatus Fullopii)* for the entrance of the Vidian nerve into the aqueductus Fallopii.

On the *cerebellur surface* is seen the *foramen auditorium internum*, the superior and posterior part of the margin of which is more prominent than the anterior, which, in fact, degenerates into a sulcus. It is the commencement of a canal (the *meatus auditorius internus)* into which pass the acoustic and facial nerves, and the bottom of which is divided by a ridge into two unequal depressions; the upper one being the *fossulu parvu*, in which is the orifice of the aqueduct of Fallopius for the exit of the facial nerve; the lower one being the *fossula mugna*, in which are several minute perforations for the acoustic nerve. Behind the foramen auditorium is an indistinct slit, which is the termination of the aqueductus vestibuli; above and rather anterior to this slit is a triangular orifice for the entrance of vessels; and below it, extending to the foramen lacerum posticum, is a slight groove.

Between the cerebral and cerebellar surfaces there is a sharp ridge on which there is a groove (the *sulcus petrosus)*, more evident posteriorly than anteriorly; to the ridge is attached the tentorium; the groove lodges the petrosal sinus.

The under surface is divided into two parts by a sharp, prominent ridge, which has on either side of it a considerable fossa. That on its outer side is the *fossa parotidca* for the upper part of the parotid gland; that on its inner side is a thimble-like depression (the *fossa jugularis)*, which forms with the occipital bone the foramen lacerum posterius. In this bone, however, it is not so wide as it is in the occipital; from which it results that the foramen is imperfectly divided into two parts—the anterior for the nerves, the posterior for the vein; and it is the latter organ which is lodged in the fossa jugularis of the temporal bone. The fossa parotidea is limited, *above* and in front, by a fissure (the *fissuru Glasseri)*, which penetrates to the tympanum and gives exit to the chorda tympani and entrance to the laxator tympani muscle; *behind*, by the *external auditory process*. The margin of the *foramen auditorium externum*, which is elliptical, has its long diameter vertical, and is the commencement of the *meatus auditorius externus;* a tube which is curved a little downwards, is more expanded at its extremities than in its middle, and terminates at the membrana tympani, *in front*, by a sulcus which is situated on the border between the cerebral and under surfaces, and passes backwards, between the petrous and squamous portions as a canal (the *canalis Eustachianus)*, which is divided by a lamina of bone, called the processus cochleariformis, into two parts, the inferior of which contains the Eustachian tube, and the superior the tensor membranæ tympani muscle. Immediately behind the fossa jugularis there is a rough surface, for the articulation of the jugular process of the occipital bone; and to the outer side of this surface is the *foramen stylo-mastoideum* for the exit of the facial nerve. In front of and close to this foramen, and between it and the jugular fossa, is the long pointed process (the *styloid process)* for the attachment of the stylo-maxillary and stylo-hyoid ligaments, and the stylo-pharyngeus, stylo-glossus and stylo-hyoideus muscles; this process is embraced on the outer side at its root by a portion of the ridge separating the parotid and jugular fossæ; that portion is called the *vaginal process.* In front of the fossa jugularis are two foramina; one very large, the *foramen caroticum ;* the other very small, to the inner side of the former and nearly on the margin between this and the cerebellic surfaces, being the termination of the *aqueduct of the cochlea.* The foramen caroticum is the inferior opening of the *canalis caroticus*, a canal which exists in the bone, and consists of two parts that are at right angles with each other—the inferior, short, vertical, and extending upwards from the foramen caroticum into the substance of the bone; the superior, horizontal, running lengthwise, and extending to the end of the petrous process: in this canal there pass the carotid artery to the cavity of the cranium, and a filament of the nervus abducens, as well as one of the Vidian, to the neck. A rough surface is observed anterior to the foramen caroticum for the attachment of the levator palati and the tensor tympani muscles.

The outer and posterior extremity of the petrous is confounded with the mastoid and squamous portions; the inner and anterior is open, and the bone is so much removed at its upper part (to allow the carotid artery to pass upon the body of the sphenoid) that it there appears more like a deep groove than a tube. This is filled up in the recent subject by a plate of cartilage, but in the dried skull, when this cartilage has been removed, there is found an opening, between the sphenoid bone and this extremity of the temporal, which is called the *foramen lacerum anticum.*

The *mastoid* portion is situated at the outer end of the petrous, and behind and below the squamous. It is of a nipple-like shape, with an upper horizontal denticulated border, with which the posterior inferior angle of the parietal bone articulates; and with a posterior semicircular border which is joined to the occipital: in both directions it is overlapped by the bones to which it is joined, except at the lower part, where it is applied to the occipital by a sort of harmonic suture.

On its *inner surface* there is a deep, semicircular sulcus (the concavity looking backwards) which traverses its entire length; it receives the lateral sinus from the parietal bone and transmits it to the lower part of the occipital: there is generally observed in it a foramen (the *foramen mastoideum)*, through which a vein of the scalp communicates with the sinus.

Its *outer surface* is roughened and gives attachment to the sterno-cleido-mastoideus, and sometimes to the trachelo-mastoideus; it terminates below in the mammillary eminence, called the *mastoid process*, behind and to the inner side of which are two grooves—the one nearest to the process (the *sulcus digastricus)* very evident, for the attachment of the digastricus; the other nearly on the articulating edge *(sulcus occipitalis)*, less distinct, for the occipital artery.

The *squamous* portion rises upwards from the mastoid, and part of the outer border of the petrous portions; it has a semicircular margin which embraces the parietal and sphenoid bones.

Its internal surface, which is concave, contributes to form the middle fossa of the cranium, and exhibits strongly the depressions and elevations which correspond to the convolutions of the brain, and to the spaces between them. At its anterior part, and commencing at the angle between it and the petrous process, there is a groove which runs upwards and divides into other grooves, some of which pass backwards; these are formed by the middle meningeal artery and its branches. The external plate of its border is prolonged upwards, in such a manner that this surface is surmounted by a rough articulating line, of considerable breadth, which is applied on the outside of the parietal and partly on the sphenoid bone.

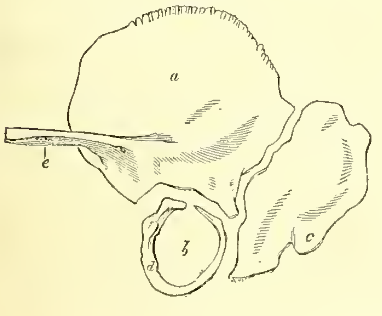
The *external surface* is slightly convex, is smooth, and there may be often seen indications of deep branches of the temporal artery having passed over it. It forms in part the *temporal fossa*, and the temporal muscle is attached to it. At its lower part, a process (the *zygomatic process)* passes transversely outwards, and is then twisted on itself in a direction forwards, after the fashion of the ribs at their angles; so that the surface of the process which would have been superior becomes internal, and that which would have been inferior becomes external. This process has two roots, an anterior or transverse and a posterior or longitudinal. The former is a convex elongated eminence, situated transversely and in front of a fossa (the *fossa articularis)*, in which the condyle of the lower jaw is placed. This root is the *eminentia articularis*, on which the condyle, with its inter-articular cartilage, is thrown when the jaw is depressed. The posterior root has itself two origins, which circumscribe the external auditory foramen; and it flows into and joins the anterior, just when that root is altering its direction. Between the squamous process, and that part of the zygomatic process which is between the two roots, there is a groove in which play the posterior fibres of the temporal muscle. The fossa articularis, which is between the roots, is bounded behind by the Glasserian fissure before mentioned; it forms, with the adjoining fossa parotidea, the *glenoid cavity*. The zygomatic process extends forwards about an inch from its anterior root; being, therefore, convex externally and concave internally. Its upper border gives attachment to the temporal fascia; its inferior (which is about half the length of the superior) to the masseter muscle. Its external surface is covered by the integument, and its internal forms the outer boundary of the temporal fossa, in which is situated the temporal muscle. The extremity of the zygomatic process forms a point, on account of the under margin being bevelled and denticulated to articulate with the malar bone.

The circumference of the squamous process is sharp, in all that part which is above the level of the zygomatic process, and denticulated, at the expense of its outer table, in the rest of its extent; so that it rests on the sphenoid bone.

The connexions of this bone and the mechanical effects which result from its position, will be readily understood. Its petrous portion being wedged between the basilar process of the occipital bone, which serves it as a fulcrum, and the ala major of the sphenoid, which binds it against that fulcrum; the inferior part of its squamous process resting on, and being sustained by the sphenoid bone, while its mastoid process is braced in by the posterior inferior angle of the parietal, and by the occipital bone — the fronting squamous margin will effectually resist the lateral thrust of the parietal; the more so that a limited yielding movement is allowed at the fulcrum. The zygomatic process advancing forwards to the malar bone, will, with its fellow of the opposite side, give stability to the several bones of the face; and, in common with the pterygoid processes of the sphenoid bone, maintain the integrity of the various arches which they form. It is also connected with the lower jaw.

This bone is developed from six points of ossification: viz. one for each of the three great divisions, and one each for the zygomatic and styloid processes and the auditory canal. At birth it consists of four pieces, the squamous (*a*), mastoid (*c*), petrous, and an in-

Fig. 374.



complete bony ring (*d*), to which the membrane of the tympanum is attached. The bony ring is the first to join, by its upper part, the squamous; after which it is consolidated with the petrous, and then extends itself outwards and backwards to form the meatus auditorius externus, and all the four pieces are then united. In infancy the bone sustains great changes; the squamous process from being straight becomes curved; the zygomatic process recedes from the squamous and increases the space between them; the mastoid portion becomes more tumid, is developed upwards and backwards, and sends forth the nipple-like process which gives to it its name. The eminentia articularis and fossa articularis from an oblique assume a transverse direction, and become, the one more concave, the other more convex. The styloid process, though ossified in its middle, is frequently, to an advanced age, connected with the bone by cartilage only.

The *parietal bone (os parietale;* Germ. *die Scheitelbeine oder Seitenbeine*) (*fig.* 372, 373 P) constitutes with its fellow the greater portion of the vault of the skull, and forms with it a sort of bridge, the corners of which on each side are fixed, the one on the great wing of the sphenoid, the other on the mastoid process of the temporal bone, the squamous process of which braces in the intervening space.

The *external surface* offers in its centre a prominence which marks the spot at which ossification commenced; and it marks also the widest part of the skull. Below this is a semicircular line (the *linea temporalis*), to which are attached the temporal fascia and muscle; still more inferiorly is a plane surface occupied by the temporal muscle; and between it and the lower border, is a lunated articular portion with converging striæ, to be applied against the squamous portion of the temporal bone. Near the posterior part of the bone and a little removed from its upper border is the *foramen* parietale, for the passage of a vein to the longitudinal sinus.

The *inner surface* exhibits the usual indications of the convolutions of the brain, and also arborescent sulci, which mainly proceed from the anterior inferior angle of the bone, and are directed upwards and backwards to the *fossa parietalis*, which answers to the parietal prominence on the outer surface; these sulci lodge the branches of the middle meningeal artery. Along the upper border is a depression, which, with a similarly disposed edge of the other bone, forms a groove for the lodgement of the longitudinal sinus, and hence is termed *sulcus longitudinalis;* near to it are sometimes seen small depressions (*fossæ Pacchionii*) for the granulations of the dura mater, called glandulæ Pacchionii externæ.

The *borders* are of various lengths; the *superior* is the longest, the *inferior* is the shortest, and the *anterior* is longer than the *posterior*. The superior is united to the same border of the opposite bone by the regular interchange of serrations of the outer table; the anterior and posterior reverse the arrangement which obtains in the frontal and occipital bones; that is, they are overlapped in the upper part, while in the lower they overlap those bones; the inferior is sharp, and merely terminates the articular surface already alluded to.

The *angles* contained within these borders are the *frontal* (which is nearly a right angle) formed by the superior and anterior borders; the *occipital* (more obtuse) by the superior and posterior borders; the *mastoidal*, truncated and articulated with the mastoid process of the temporal bone; and the *spinous* (acute) received on the tip of the great wing of the sphenoid, and intervening between the temporal and frontal bones. The mastoidal angle is, on its inner surface, traversed by a sulcus (the *sulcus lateralis*) to lodge the lateral sinus and to transmit it from the occipital to the temporal bone. The spinous angle is deeply grooved on its inner surface by the *sulcus spinosus* for the middle meningeal artery, or the arteria spinalis duræ matris; this groove has its place frequently supplied by a canal, then called *canalis spinosus*.

Its connexions are with its fellow above; the temporal and sphenoid below; the frontal before; and the occipital behind.

The parietal, like each half of the frontal bone, is developed from the protuberance; and from this point the ossific matter radiates towards its several borders. While this process is going on, the part above and the part below the centre form a considerable angle with each other; but this is much effaced when the edges have arrived at their destination, especially when the squamous process of the temporal quits its vertical for its curved position.

Articulation of the cranial bones.— These several bones are locked together so as to form the envelope of the brain, and the mode by which their secure adherence to each other is effected, differs in the summit, on the sides, and in the base of the cranium.

In the calvaria they are united either by the overlapping or by the dove-tailing of their edges, or else by the two modes combined. The inner table does not proceed so far as the external, and the latter being jagged with processes which have no definite form, but which are either tortuous, or narrower at their fixed than at their free extremity, the outer tables are immovably joined by the fixation of the processes of each side into the spaces of the other. By this means the inner tables of the two bones are brought nearly into contact, a thin lamina only of cartilage intervening; so that on looking into the vault, but little more than a plain line will be noticed. Here, however, there is no overlapping of the outer tables; but the only instance of it is in the junction of the two parietals on the median line, by which, in effect, they form but one bone. On the sides of the skull there is a mere overlapping of the descending by the ascending portions, and to accomplish this, and yet maintain uniformity of surface, those parts of the outer tables which project beyond the inner are pared off or thinned in opposite directions. Thus the squamous processes of the temporal bones and the great wings of the sphenoid rise upwards from a fixed basis and form a wall which is bevelled off on the inner edge of its outer plate, so as to receive the parietal and frontal bones, the outside of which sustains a corresponding bevelling, by which arrangement they are prevented from being thrust outwards. The articulation of the anterior and the posterior with the middle portion of the calvaria, is a modification of the two preceding; that is, the outer table is partly bevelled and partly denticulated. The frontal and occipital bones are symmetrical and single, while there are two parietal; and, though these are well united by their mutual interchange of denticulation, they are yet more firmly consolidated by the extension of the frontal and occipital bones on the frontal and occipital angles of the parietals, and on their borders to some distance from those angles; each symmetrical bone thereby forming a species of cramp on the parietals. The edges, however, of the outer tables are not pared to a sharp ridge, but there is left sufficient to be fashioned into processes to maintain the security of the skull in a longitudinal direction. The parietals being thus firmly secured above and below, the intervening portion of their edges is competent to act as girders themselves, and, in fact, we find that the lower part of their anterior and posterior borders overlap the corresponding portions of the frontal and occipital bones respectively.

In the base of the cranium the bones are placed in simple contact, and are so disposed that forces, descending from above, will necessarily drive them closer to each other. To understand this rightly, we must suppose the sphenoid and occipital to form (which, in fact, they do) but one bone at an early period of life. The temporal bone is placed alongside the occipital, in such a way that the petrous process is wedged into the angle between the basilar process of the occipital, and the great wing of the sphenoid; while the latter, again, is wedged into the angle between the petrous and squamous processes of the temporal bone. It has been said that on the upper surface of the outer margin of the great wing, rests the lower part of the squamous process; in case of force descending through the parietal bone this will be the fulcrum, and the lever (the squamous process) being directed outwards, the mastoid and petrous processes will necessarily be squeezed more forcibly against the occipital bone and its basilar process.

The peculiar appearance presented by the articulations on the outer surface of the calvaria, has procured for them the name of *sutures*, a term which is applied frequently to the joinings in the base, although they are essentially different in appearance and in fact. Those which are situated in the calvaria, and to which the name is more suitable, are the *coronal, lambdoidal*, and *sagittal sutures*.

The *coronal* suture extends between the two great wings of the sphenoid bone across the upper part of the skull, and connects the frontal to the two parietal bones (*fig.* 373, *a*). The *lambdoidal* (*o*) consists of two diverging lines formed by the articulation of the posterior border of the two parietals with the superior half of the occipital; and extends from the superior to the lateral angles of that bone. The *sagittal* is the line of union between the parietals themselves, and runs longitudinally from the superior part of the lambdoidal to the centre of the coronal suture. On each side of the skull is the *squamous* suture (*fig.* 373, *e*); it has none of the serrated characters of the other sutures, but is an arched line extending from the great wing of the sphenoid to the mastoid process of the temporal bone, and traversing so much of the border of its squamous process as embraces the parietal bone.

The squamous suture and the lambdoidal suture are connected by a short transverse line formed by the articulation of the mastoid angle of the parietal bone with the mastoid process of the temporal, and which is called *additamentum suturæ squamosæ* (*fig.* 373, *g*). From the lateral angle of the occipital bone to its jugular process, that is, from the termination of the lambdoidal suture (where it is joined by the before-mentioned supplement of the squamous suture) to the jugular foramen, there is a line formed by the posterior border of the mastoid process and the occipital bone termed *additamentum suturæ lambdoidalis.*

The *transverse frontal suture* (*fig.* 373, *d*) is situated transversely, but forms several angles in its course. It extends from one external angular process of the frontal bone to the other; commencing at either angle, after uniting that angle to the malar bone, it enters the orbit, and unites the frontal bone to the great wing and to the small wing of the sphenoid; it then passes out of the other side of the orbit, joining the same bone to the ethmoid, lachrymal, nasal process of the superior maxillary and nasal bones themselves; enters the orbit of the opposite side and retires from it, articulating the frontal to bones analogous to those in the other orbit.

Other sutures are occasionally enumerated, such as the *sphenoidal*, which entirely surrounds the sphenoid bone; and the *ethmoidal*, which bounds the cribriform plate of the ethmoid bone. Both of these, so far as they deserve the name of sutures, are comprehended in the transverse frontal suture.

The articulations of the temporal with the occipital, sphenoid, and parietal bones have been designated as the petro-occipital, petro-sphenoidal, spheno-temporal, and spheno-parietal sutures; but, with the exception of the last, (which is squamous, and truly a part of that suture,) they are not sutures.

It ought further to be remarked that, while the bones of the calvaria are much thinner than those of the base, they are comparatively thicker in their borders to allow of that serration from which the term suture is derived.

To study, in combination with each other, the facts enumerated in the foregoing description, it is necessary to take a survey of the external and internal surfaces of the skull itself.

For this purpose the external surface may be divided into four regions: the superior, the inferior, and the two lateral.

The *superior region* extends from the nasal process of the frontal bone to the occipital protuberance, and is bounded on each side by the linea temporalis; a curved line, which, commencing at the external angular process of the frontal bone, passes backwards, traverses the parietal below its protuberance, and is received on the extreme point of the root of the zygomatic process of the temporal bone. To proceed from before to behind, there are, on the median line, the nasal process and the rough notch for the articulation of the nasal bones; the nasal protuberance; the glabella bounded laterally by the frontal processes; the line indicating the junction of the two fœtal portions of the frontal bone; the centre of the coronal suture; the whole length of the sagittal suture, with the foramen parietale on each side of it; the superior angle of the occipital bone; a part of the occipital bone itself; and, lastly, the occipital protuberance. Laterally, and on each side, there are the frontal process, the superciliary ridge, the depression between them, and the supra-orbitary foramen; the frontal protuberance; the coronal suture; the parietal protuberance; the lambdoidal suture; and so much of the side of the occipital bone as is above the transverse ridge.

The *inferior region* extends from the posterior part of the nasal process to the occipital protuberance, and is circumscribed by a line, continuous with the extremities of the superior curved ridge of the occipital bone, and passing on the outside of the mastoid and in the direction of the zygomatic process of the temporal bone, to the crest which is on the temporal process of the great wing of the sphenoid. The facts to be here noticed are numerous, and, to facilitate their enumeration, this region may be divided into three parts, one anterior to the pterygoid processes of the sphenoid bone, one posterior to the articulating processes of the occipital bone, and a middle one between these two.

The anterior division contributes to form the nose and the orbits. For the first, there may be observed on the median line, the nasal lamella of the ethmoid bone, articulated, in front, to the nasal process of the frontal, and, behind, to the crest in front of the body of the sphenoid. On the same line, but below and behind this, is the azygos process, and inferior part of the body of the sphenoid, with the channels to form, with the vomer, the palatine canals. On either side of the nasal lamella is the slit for the ethmoidal nerve and vessels; the cribriform plate and its foramina; and the space which assists to form the nares. More laterally, and still passing from before backwards, is the internal angular process of the frontal bone, to unite with the lachrymal; the cellular mass of the ethmoid, with its turbinated processes on one of its sides, and the orbitar plate on the other; the junction of this mass to the body of the sphenoid; the turbinated process of the same bone, and, sometimes, the opening into its sinus; the articular surface for the palate bone; and, lastly, the base of the pterygoid process exhibiting the anterior orifice of the Vidian canal.

Still more outwardly is the part which forms the orbit, concave, and broader before than behind. To the fore part there are, on the outer side, the lachrymal fossa; on the inner side the trochlear fossa, and, near to it, the orbitar orifice of the supra-orbitary foramen. Further back there is on the inner side a portion of the transverse suture between the frontal and ethmoidal bones, containing the two internal orbitar foramina; and, to the outer side, another portion of the same suture between the frontal and sphenoid. A third, shorter portion connects the two preceding, and unites the frontal to the small wing of the sphenoid. Behind this there are in succession the foramen opticum; the foramen lacerum orbitale superius; the foramen rotundum; and, lastly, the sulcus temporalis leading from the last foramen, and being behind the orbitar process of the sphenoid bone.

The middle division offers in its centre the basilar process of the occipital bone, and the line of its junction with the sphenoid. On it are seen the indications of the attachment of the pharyngeal and anterior recti muscles. Its posterior edge forms a segment of a circle to assist in forming the foramen magnum. On either side, and from before backwards, are the external and internal pterygoid processes, with the fossa navicularis, fossa pterygoidea, and hiatus palatinus between the two processes; the posterior orifice of the Vidian canal; the foramen lacerum anterius; the under surface of the petrous process of the temporal bone, with, on one side, the line of its junction with the basilar process, and, on the other, the line of its junction with the sphenoid bone, the Eustachian sulcus occupying the latter; behind the foramen lacerum anterius is the rough surface for the origin of the levator palati and tensor tympani muscles; the inferior orifice of the carotid canal; the opening of the aqueduct of the cochlea; and, lastly, the foramen lacerum posterius. More outwardly, and pursuing the same direction, are the under surface of the great wing of the sphenoid bone; its line of union with the temporal; the processus articularis; the fossa articularis; the Glasserian fissure; the fossa parotidea; and, lastly, the rough inferior border of the foramen auditorium externum. On the inner edge of this plane, and to the outer side of the sulcus Eustachianus, there are, successively, the foramen ovale; the foramen spinale; the styloid process; the spinous process, which is wedged into the Glasserian fissure; the crest between the fossa parotidea and the foramen lacerum posterius; the vaginal process and the styloid process.

The posterior division exhibits, on the median line, the foramen magnum; the longitudinal spine bisecting the inferior curved ridge, and having, on each side, below that ridge, rough depressions for the attachment of the posterior recti muscles, and above that ridge, still stronger and larger marks of the attachment of the complexus; and, lastly, the inferior aspect of the occipital protuberance. To the extreme outside and passing from behind forwards, there are the termination of the superior occipital ridge; the additamentum suturæ lambdoidalis; the posterior part of the mastoid portion of the temporal bone displaying the foramen mastoideum; the sulcus occipitalis on one hand, the mammillary process of the mastoid portion of the temporal bone on the other, and the sulcus digastricus between the two; and, lastly, the foramen stylo-mastoideum at the bottom of the sulcus digastricus. Midway, and between the median and outer portions of this region, and still passing from behind forwards, there are, the superior occipital ridge, the inferior occipital ridge, and between them the marks of the attachment of the splenius capitis and trachelo-mastoideus; the oblique surface into which the obliquus capitis superior is inserted; the posterior condyloid fossa, containing the posterior condyloid foramen whenever it exists; the condyle itself; the anterior condyloid fossa and foramen; and, lastly, to the outside of the condyle, the processus lateralis.

The lateral region (*fig.* 373) is oval, and its boundaries have already been stated. Its surface, lengthwise, is undulated, being convex behind, where the temporal and parietal form it; and concave in front, where the temporal and sphenoidal enter into its composition. Proceeding from above downwards, and commencing with the linea temporalis, we have so much of the parietal and frontal bones as are below that line, with the inferior extremity of the coronal suture between them; next, the sutura squamosa between the parietal and temporal bones, and part of the transverse suture between the frontal and sphenoid; below this, the squamous process of the temporal bone, and, in front of it, the temporal process of the sphenoid with the line of articulation between them. These parts form the *fossa temporalis*, which is limited inferiorly, on the sphenoid by a crest which divides it from the jugal fossa belonging to the face, and on the temporal by a groove on the upper part of the two roots of the zygomatic process, in which play the posterior horizontal fibres of the temporal muscle. Passing from behind forwards, there will be observed at the lower boundary of this region, the additamentum suturæ squamosæ; the base of the mastoid process; the foramen auditorium externum; and, lastly, the zygomatic process of the temporal bone articulating anteriorly with the malar bone.

The interior of the cranium presents throughout its entire extent more or less evidence of the adaptation of its surface to the convolutions of the brain.

The base is bounded, in front by the foramen cœcum; behind, by the centre of the internal crucial spine; and, in its circumference, by a line passing on each side along the outer border of the orbitar process of the frontal bone, the junction of the parietal and sphenoid; the parietal and temporal bones; and the lateral limb of the internal crucial spine of the occipital.

It is placed obliquely downwards and backwards, and consists of three principal divisions or platforms—the posterior being the lowest, the anterior the highest; and the middle, on a plane between the two.

The anterior division is called the *anterior fossæ*, and sustains the anterior lobes of the brain. It is concave in the middle and convex on each side; it is limited, anteriorly by the merging of the orbitar processes into the general mass of the frontal bone, and posteriorly by the posterior margin of the alæ minores. On the median line, from before backwards, we encounter the foramen cœcum; the crista galli; the ethmoidal process of the sphenoid bone; and, lastly, the smooth surface of that bone on which the olfactory nerves repose. On either side of the crista galli is the processus cribrosus, with its foramina, and slit for the ethmoidal nerve and vessels; more outwardly, is the transverse suture uniting this process to the frontal bone, and in it may be seen the internal orifice of the anterior internal orbitar foramen. From hence outwards, is the orbitar process of the frontal bone, somewhat arched, and displaying, more evidently than in the rest of the skull, the digital impressions of the brain; behind this is the transverse suture uniting it to the small wings of the sphenoid bone; and, lastly, there is the upper surface of the small wings themselves.

The *middle fossæ* consist of two large fossæ laterally, and one, which is smaller, centrally. This latter is the pituitary fossa; in its front is the olivary, and, behind it, is the basilar process; on its sides are the sulci carotici, and its corners are bounded by the ephippial or clinoid processes. In front of the olivary process is the groove on which the optic nerves decussate; and between it and the anterior ephippial processes of each side is the foramen opticum.

The lateral fossæ are very deep and of an irregular triangular figure, the base of which is directed outwards. Anteriorly they are bounded by the small wings of the sphenoid bone, and posteriorly by the ridge which separates the cerebral from the cerebellar surface of the petrous portion of the temporal bone. Each is formed, anteriorly and internally, by the great wing of the sphenoid; posteriorly, by the cerebral surface of the petrous process; and, externally, by the squamous process of the temporal bone. In it are seen the lines of junction between these parts, and the sulci formed by the spinous artery of the dura mater. At its anterior boundary there is the foramen lacerum orbitale superius; and behind it, inclining gradually outwards, there are in succession, the foramen rotundum, the foramen ovale, the foramen spinale, the sulcus Vidianus, the hiatus Fallopii, the depression for the Gasserian ganglion, and the processus semicircularis. To the inner side of this range, and on a level with the foramen ovale, is the foramen lacerum anterius.

The *posterior* division extends from the basilar process of the sphenoid bone to the internal tubercle of the occiput. Its margin is of a triangular figure, with its base curved and directed backwards. The petrosal ridges form the sides of the triangle, and the lateral limbs of the internal crucial spine, its base. On the median line and passing backwards we observe the superior sulcated surface of the basilar process, with a groove on each side for the basilar sinus; the foramen magnum with the anterior condyloid foramina near its anterior part; and, lastly, the inferior limb of the internal crucial spine, separating the two great cerebellar fossæ. Each of the latter is bounded, above and to the outside, by a broad groove for the lateral sinus, which groove passes from the occipital bone to the mastoid angle of the parietal, from thence to the mastoid process of the temporal (where the mastoid foramen opens into it), and, ultimately, to the occipital bone again, where it turns forwards to the foramen lacerum posterius. In this groove is seen the termination of the lambdoidal suture, and the additamentum suturæ squamosæ and the additamentum suturæ lambdoidalis cross it; the principal portion of the latter being seen in the cerebellar fossa. Anteriorly, and above the foramen lacerum posterius, is the cerebellar surface of the petrous process of the temporal bone; exhibiting the openings of the meatus auditorius internus and of the aqueduct of the vestibule; and, on the ridge which separates this from the cerebral surface, the groove for the petrosal sinus.

The calvaria possesses in its centre a dense curved rib, which extends through the roof from the anterior to the posterior part of the base, but which is more evident at its extremities than in its middle, where it is generally marked by a groove for the longitudinal sinus. The frontal spine commences it, and its termination is the superior limb of the internal crucial spine; the intermediate portion (where it is masked) is the sagittal suture. On each side, and from before backwards, we notice in succession the frontal depression; the coronal suture; the parietal depression, and several arterial sulci running towards it from below; part of the lambdoidal suture; and, lastly, the cerebral fossa of the occipital bone. On each side of the sagittal suture are the fossæ Pacchioni, and, near its back part, the foramen parietale.

A comparison of the external and internal surfaces of the cranium establishes the fact that there is a general correspondence of the two as far as regards those parts which are in contact with the periphery of the brain. But, between the several divisions of that organ, there are developed on the inside of the skull very large ribs and processes which destroy the particular correspondence of the two surfaces.

Nevertheless, this does not impair our ability to deduce the internal capacity of the cranium from an examination of its exterior; since the diploë between the two plates, in the spaces intermediate to these ribs, seldom varies more than one or two lines in its thickness.

In a skull of ordinary capacity, the length, measuring from the frontal spine to the longitudinal sulcus, is five inches and a half; its width, between the bases of the petrous processes of the temporal bones, four inches and a half; between the parietal fossæ, five inches; and between the extremities of the alæ minores, three inches and three quarters: its depth, from the foramen magnum, four inches and a half, from the ephippium three inches and a quarter; and, from the front of the olivary process, two inches and three quarters. But observation proves to us that there is little dependence to be placed on these measurements; scarcely any two skulls agree in their diameters, for where one exceeds in a given direction, it may fall short in some other. To this conclusion we shall be led by the examination of skulls, not only of members of the same community but even of persons connected by the closest ties of consanguinity. While, however, there is any doubt about the matter, it is not to mixed communities we should have recourse in our search for facts; but rather to the well-authenticated skulls of such tribes as inhabit parts of the globe remote from each other, and whose manners and customs have, to the best of our belief, remained stationary from time immemorial; for by this procedure we shall avoid the confusion arising from a mixture of different races of men whose respective dispositions have been modified by intermarriage.

The skulls of a North American Indian and a Hindoo will be good examples to shew how the diameters will vary. By making a longitudinal section of each, we shall find, by applying a line between a spot about five-eighths of an inch above the root of the nose, and another about three-eighths of an inch above the superior angle of the occipital bone, that there is considerably more space above the line in the Hindoo than there is in the American Indian, while the distance to the foramen magnum is much greater in the latter than in the former. Again, if we make the usual horizontal section, it will be manifest that in breadth the Indian will exceed the Hindoo by nearly, and, sometimes, more than an inch, although the latter has the advantage in length.

In the Negro, which, in length, is equal to the Hindoo, the space above the line in a vertical section is not *absolutely*, much less *relatively*, so great towards the frontal bone as in the shorter skull of the Indian; while towards the posterior part of the parietals it is much greater, and in its breadth it falls but little short of it.

These three aboriginal types will suffice to shew the endless varieties which must prevail in mixed communities, and to satisfy us that the forms of skulls are as numerous as the diversified modifications of character with which the Creator has endowed the human race.

Several naturalists have sought to establish an analogy between the cranium and the vertebræ, and have imagined that they had discovered in the one a type of the other; in other words, that the cranium is neither more nor less than a gigantic vertebra which has been submitted to some necessary modifications.

In this sense the ephippium and basilar portion of the occipital bone represent the body of a vertebra; the foramen magnum, the vertebral foramen; the longitudinal spine of the occipital bone, the spinous process; the expanded portion of the bone as far as the mastoid portion of the temporals, the vertebral plates; the mastoid processes themselves, the transverse processes; the eminence above the anterior condyloid foramina and the condyles themselves, the superior and inferior oblique processes; and the notch behind the condyles and the jugular notch, the notches which form the conjugal foramina.*

Others again regard the cranium as composed of several vertebræ more or less complete, which are so associated as to meet the exigencies of the highly developed summit of the medulla spinalis. The resemblance, however, of many of the parts to a vertebra is so imperfect as to admit of the greatest license, as respects both the fixing of the number and the apportioning of the parts which severally belong to them. The alteration of position, too, to which they are necessarily subject to enable them to accord with the change in direction which the nervous matter sustains, casts much confusion on the subject, and prevents the mind from recognizing, at once, a similarity which would be more apparent if they continued to be superimposed on each other as they are in the spine instead of being arranged at right angles with it.†

The occipital bone certainly offers no difficulty to the detection of an analogy between it and a vertebra; and we readily discern in it a body; a foramen; two transverse, four articular, and one spinous process; and four notches. These have already been pointed out, and it is sufficient here to observe, that, in this bone apart from the others, the basilar process alone will represent the body, and the lateral processes will be the type of the transverse processes of the vertebra.

By removing the bones of the face and taking the sphenoid in conjunction with the frontal bone, we shall (if we place the body

* This was Dumeril's theory.—See Consid. gén. sur l'Analogie entre tous les os et les muscles du tronc des animaux. — Magasin Encyclopédique, 1808, t. iii.

† The celebrated Goëthe was among the first to adopt this idea. He admitted the existence of three vertebræ in the cranium, (Zur Naturwissenschaft überhaupt, &c. Stuttg. 1817-24.) The further development of it occupied the attention of O'Ken, Spix, Meckel, Geoffroy St. Hilaire, and Carus.—See Meckel, Anat. Desc. &c. t. i. p. 631, and Carus, Anat. Comp. par Jourdain, t. iii. Introduction.—Ed.

of the sphenoid bone vertically) at once perceive the same analogy to exist. If, when they are thus placed, we look at the cerebral surface, we shall recognize the body in that of the sphenoid; the vertebral plates in the small wings of the sphenoid, and two halves of the frontal bone; the foramen in the space circumscribed by these last; the transverse processes in the two great wings of the sphenoid; and the notches in the lacerated orbitar foramina, and the angles between the body of the sphenoid and posterior margin of its great wings. If we look at it in front, it will not require any great stretch of the imagination to recognize the four articulating processes in the pterygoid processes of the sphenoid bone and the external angular processes of the frontal.

The temporal and the parietal bones together represent another vertebra, situated between the former two. By looking at the base of the skull held vertically, and abstracting in the mind the occipital bone, we can (under favour of the license allowed to, or taken by anatomists) see in the two petrous portions of the temporal bones, if they were brought into contact, a type of the body of a vertebra; and in those parts of them which contribute to form the anterior and posterior lacerated foramina, we observe a resemblance to those notches which form in the vertebræ, as they do here, conjugal foramina. The articular eminences of the temporal bones give us no bad notion of the transverse processes, while the zygomatic processes above (still holding the skull vertically) and the part which projects behind the mastoid processes below, will indicate the four oblique or articulating processes. Lastly, the squamous processes of the temporal and the whole of the parietal bones represent the vertebral plates, and the space enclosed by them, the vertebral foramen.

Development of the cranial bones. — The progressive development of the bones of the cranium has been pointed out in their separate descriptions; but there are some general facts which regard its formation as an entire organ which merit further notice.

The cranium of the fœtus presents, like all other organs, a rude outline of the shape it is destined to assume; and, at the earliest period at which it is noticed, its walls are completely membranous, being formed by the dura mater and pericranium so united as to render it impossible to separate them without injury. Very early points of ossification are developed in this membranous envelope, whence osseous radii shoot out, so that the several points enlarge towards each other, and ultimately coalesce or are united by suture.

Unlike other bones of a similar character the opposite surfaces are not of similar density. The surface secreted by the vessels of the dura mater contains less animal matter than that which is produced from the vessels of the pericranium; and it is, therefore, of a more dense and brittle character; so much so, that, when the contiguous bones approximate, the edges of the inner table are simply in juxta-position, a slight layer of cartilage alone separating them. Hence, in the interior of the skull, the sutures are plain lines; or, if at all irregular, there is no interchange of substance between them. Not so, however, with the external. By reason of the greater quantity of animal matter which it possesses, and the more diffuse character of its texture, a principle of toughness is conferred on it which admits of its being dove-tailed with the same table of other bones.

The base takes precedence of the calvaria in the commencement and completion of its ossification. With the exception of its most prominent points, and the ethmoid bone, it is completely ossified at birth; while, between the bones of the calvaria, there are considerable membranous interspaces, so as to allow of these bones being squeezed together, or to overlap each other, at the period of parturition. The ossific matter departing from the protuberances of the frontal and parietal bones (*c*, *d*, *figs.* 374, 375) and radiating towards the circumference of these bones, it follows that the angles will be incomplete when the rest of the bone is formed. On this account it is that, at the four angles of each parietal bone, there is a membranous spot which the ossific matter has not reached, when, in other parts, it is joined to the surrounding bones. These spaces are called *fontanelles;* two of them are situated on the median line and superiorly; and two others inferiorly and in each lateral region. The *posterior superior fontanelle* is triangular, and is found between the superior angle of the occipital bone, and the occipital angles of the two parietal. The *anterior superior fontanelle* (*a*, *fig.* 376), by reason of the frontal bone being formed in two parts, is of a lozenge shape; and it is between those two parts and the frontal angles of the parietal bones that it occurs. These two fontanelles are consequently at the extremities of the sagittal suture. The *inferior fontanelles* are found, the *anterior* (*a*, *fig.* 375) between the spinous angle of the parietal, and the great wing of the sphenoid bone; the *posterior* (*b*, *fig.* 375) between the mastoid angle of the first-named bone and the mastoid process of the temporal. These two fontanelles are, therefore, situated at the extremities of the squamous suture.

Fig. 375.

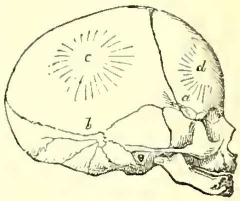
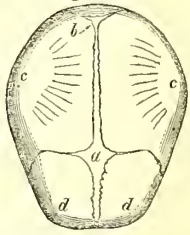


Fig. 376.



In infancy the relative proportion of the cranium to the face is much greater than in adult life; and this causes the foramen magnum to appear to be situated much further forward, in the inferior region of the base, than it is when the face is more expanded.

Fig. 377.

The lower part of the occiput is flattened, the superior is very projecting, and, altogether, the cranium has a character of rotundity which is speedily exchanged for the oval form which prevails in the adolescent age.

When the sutures have become conjoined, and the cranium is constituted a defensive investment of the brain in virtue of its mechanism, the internal table (the *tabula vitrea)* is secreted in greater abundance, and the diplöe between it and the outer table is rendered more manifest. The spongy tissue of the sphenoid bone is absorbed and the sinuses formed; but it is not until a period nearly coeval with puberty, that those of the frontal bone are developed.

It is not until the diplöe is fully formed that we can demonstrate those venous canals with which that structure has been shown to abound by the researches of Chaussier, Dupuytren, and Breschet *(figs.* 187, 188, p. 436).

Mechanical adaptation of the cranium.—It will now be noticed that the properties of the cranium, those on which its defensive qualities are founded, differ in the several periods of life; but that, nevertheless, there is in each as perfect an adaptation of it to these purposes as seems consistent with the schemes of Providence in the creation of a finite being.

The pressure which the brain has to sustain during the process of parturition, is directed solely to that part which is not essential to life; the condition of the bones of the calvaria admits of the volume of the hemispheres being diminished at the time the fœtus is ushered into the world. Not so the base; the parts which it is destined to protect require to be maintained in all their integrity, and the extent to which it has acquired solidity is such as to forbid the encroachment of the parietes on parts which are essential to the continuance of life, and which are highly intolerant of pressure.

In infantile life, also, protection is afforded on the same principle. The bones of the calvaria are notoriously capable of sustaining indentations, and afterwards, by their resiliency, of regaining their normal form. The preponderance, too, of the organic over the inorganic texture, blunts the force which may be applied, and resists its transmission to the parts below. But there is an addition even to these provisions, a mechanical disposition of the bones highly favourable to resistance. At the back, on the sides, and in front—opposed in every direction from which force may proceed—are the summits of ovoidal domes, and, as the ossific matter radiates from these summits to the circumference, the force will be received on one extremity of a bundle of diverging lines, and that which would sever the structure if it fell on any other point, here falls comparatively innoxious. Hence it is that the centers of ossification are so much more projecting during infancy than in after life; for, although the mechanical contrivance abides through the whole term of existence, it is not, when associated with other means, of that predominating character which we observe in youth.

The manner in which the cranium (when fully formed) defends the brain, differs widely from the preceding. In proportion as its several parts become consolidated, and the relation between its animal and earthy constituents is reversed, so its power of deadening or neutralizing the vibrations which pass through it, is diminished. It is here on its general shape and the disposition of its parts that its protective properties depend.

It has been already stated that the bones of the cranium are so fashioned as to concur in the production of an egg-like cavity; and that their margins are so arranged as to enable them to bind and be bound by each other, in such a manner that if one bone be taken away the whole will have a tendency to separate. This ovoid form ensures (much better than any other which has no fixed basis or point of resistance beyond itself) the transmission of the vibrations which are distributed from any spot on which force may be applied.

Assuming that the skull involved the properties of an arch, its defensive power has by some been attributed to the circumstance of its being of that figure. An arched form, however, would serve it only in the case of force descending from above; it would not provide resistance to those severe shocks which are communicated from below, as in jumping, nor protect it from blows that might arrive on its sides.

But the cranium is not an arch, for there are neither piers on which the extremities of that arch could rest, nor abutments to resist their lateral thrust. Supposing a barrel to be sawed lengthwise, and the edges to be connected by a base, if the centre be applied on a column, (the proportion of which to the base is the same as that of the spine to the width of the skull,) it is manifest that, since the extremities of the arch are received on the ends of two long levers which have a common fulcrum, an inconsiderable force would have a tendency to sever them at their junction. On the other hand, if the barrel were entire, force would be transmitted through the parietes to a point exactly opposite to that on which it impinged, if it were not dissipated in its transit. Such a degree of force however might be applied, that its vibrations, distributed at the moment of its application, might pass through the entire walls, and, accumulating at one spot, by their intensity cause the fracture of the part. The natural mode of providing against this occurrence would be to strengthen the part in which (from the situation of the organ) these vibrations might, in general, be expected to concur; and this is the contrivance adopted in the cranium, for in the centre of its base there is a quadrilateral portion (the body of the sphenoid bone) of characteristic massiveness and strength.

It does not however augment uniformly in its substance from above downwards. The matter is accumulated in dense lines or ribs, which pass to a common centre, and constitute thereby a peculiar skeleton or frame-work of surpassing strength, which admits of the introduction of a lighter and more fragile structure in the intervening spaces, and resists the shocks that arrive through the spine, from behind or from above.

This frame-work is situated almost entirely in the base; the only part which is in the calvarium being a longitudinal curved line, formed by the ethmoidal process of the sphenoid bone, the crista galli of the ethmoid, the spine of the frontal, the thickened commutual margins of the parietals, and the superior limb of the internal occipital spine. Independently of this curved rib, the calvarium consists of four ovoidal domes, two on each side; formed, the anterior by the corresponding half of the frontal bone, and the posterior by the parietal. The summits of these domes are their centres of ossification, and their bases abut, partly on the longitudinal rib, and partly on the frame-work in the base.

The part to which all the forces tend is the body of the sphenoid bone. From its posterior corners there pass backwards two ribs, (the petrous processes of the temporal bones,) which terminate on the extremities of an arch, (the lateral limbs of the internal crucial spine of the occiput,) which is placed horizontally, and the convexity of which is turned backwards.

This arch and the two ribs which connect it to the centre are in the line in which the occiput would strike the ground in falling backwards; and they further form the brim of the pit which contains the cerebellum, so that the vibrations of force pass in the interstice between that organ and the cerebrum.

From each side of the body of the sphenoid bone there stretches forwards, outwards, and upwards towards the temples, a curved rib, (the anterior part of the great wing,) and, from the anterior part of the body, a transverse rib which overlays the former. These and the posterior lateral ribs, all of which depart from a common centre, constitute the frame-work of the base which sustains the ovoidal domes of the calvaria. The frontal dome is placed with its summit (the frontal depression) looking backwards, downwards, and inwards; its margin is received, inferiorly on the whole length of the anterior transverse, and on the extremity of the anterior lateral curved rib; towards the middle line, on so much of the longitudinal rib as extends to the parietal bones; and superiorly, it is applied against a portion of the base of the parietal dome. It is against these parts that it thrusts, whenever it receives a shock on its summit. The parietal dome is placed with its summit (the parietal depression) looking downwards and inwards. Below, it is received on the extremities of the lateral ribs; above, it thrusts against the remainder of the longitudinal rib; behind, it falls on the corresponding portion of the horizontal arch; and, in front, it antagonizes the frontal.

It is by the bases of these domes thus thrusting against a solid frame-work, that the cranium is endowed with the power of resisting lateral shocks whether they approach from before or behind; and it is not, as some allege, simply by the mobility of the head, that it withstands blows, which, if it were fixed, would fracture it.

There yet remains to be noticed an important part of this skeleton or frame-work; that which bears upon the spine, and resists the force transmitted through it. At the bottom of the pit containing the cerebellum, there is an elliptical opening (the foramen magnum), the margin of which is very dense; this opening is provided underneath with two tubercles (the articulating processes), by which it rests on the vertebral column; from these tubercles a curved rib on each side (the lateral process of the occipital bone and the mastoid of the temporal) extends upwards and outwards to the extremity of the posterior lateral rib; the segment of the margin of the opening which is anterior to the tubercles, is prolonged upwards and forwards, in the form of a broad pillar (the basilar process), to the back part of the common centre; the segment which is behind the tubercles sends off, at its back part, a spine (the inferior limb of the internal crucial spine), which ends at the centre of the horizontal arch, at the point where the superior longitudinal rib terminates; and this point of confluence of the forces from below, from above, and from behind, is strengthened by a nodule (the internal occipital protuberance). The frame-work of the cerebellar cavity is thus connected with that of the general cavity; anteriorly, to the body of the sphenoid bone; posteriorly, to the tubercle of the occipital; and, laterally, to the extremities of the petrous processes of the temporal bones. In both of them it will be seen that they occupy spaces between the grand divisions of the nervous matter, which latter is, therefore, removed from the chance of sustaining injury by shocks, much more completely than it could have been had the parietes been submitted to a progressive augmentation of substance from above downwards. As it is, the spaces in which the nervous matter reposes are thin and frequently diaphanous; and, were they situated in unprotected parts, would be perforated by the slightest force.

During a considerable period of life the subject enjoys additional protection from the slight yielding of the bones, and from the cartilage which intervenes especially at the base. Pressure applied on the vertex would tend to disjoin the parietal bones from each other, and from the frontal and occipital bones. This the peculiar nature of the articulations forbids, and the longitudinal rib chiefly, and the expanded portion of the bones themselves in part, convey the force downwards, the former *forwards* through the median line of the ethmoid to the front of the sphenoid, and *backwards* through the superior and inferior limbs of the crucial spine of the occiput, traversing the foramen magnum, and passing through the basilar process to the back of the sphenoid bone: the latter *forwards* through the frontal bone to the small and great wings, and, through them, to the body of the sphenoid; and *backwards* through the parietal and occipital to the lateral limbs of the crucial spine. The parietals convey it down the sides to the great wing of the sphenoid and the mastoid process of the temporal bone, from which it is transmitted to the common centre; and the slight rotation which is permitted to the temporal bone, (and which has already been alluded to,) materially tends to break the force in its transit. Nor is there any imperfection in this apparent inclination of the parietals to an outward divergence, for the squamous process of the temporal bone which overlaps each between its two fixed points is strongly supported on its outer side by the temporal muscle.

Abnormal conditions of the cranium.

Most of the abnormal conditions of the cranium are dependent on circumstances connected with the evolution of the brain, and are mostly acquired after birth; the only congenital variations being those in which there is a total or a partial privation of its parietes.

There is no vestige of it, or, indeed, of the head itself, in the true acephalous fœtus; but, whenever the medulla oblongata is present, the base of the cranium is developed, and oftentimes there are found rudimentary portions of the other bones (*false acephalia* and *anencephalia).*

The parietal or occipital bones, and sometimes all of them are imperfect in that malformation termed encephalocele, which, in some cases, is analogous to spina bifida, and, in others, to hernia cerebri. When serous fluid constitutes the tumour, the deficiency of the bones is considerable, owing to the arrestation of the formative process; but when the brain protrudes, their development continues in such a way as to embrace the root of the tumour, and then the calvaria, flattened and in contact with the base, exhibits an opening through which the hernia escaped.

The cranium is said to be, at times, insufficiently evolved; the evolution of its parts being accelerated and their coalescence prematurely effected, so that the ossific capsule is formed before the brain has attained its full growth. It is, however, most probable that in this as in other cases it adapts itself to the brain, and that it is on an imperfect development of that organ that the smallness of the cranium is dependent; but varieties of this description which are connected with deficiences of mental endowment will scarcely admit of enumeration.

The parietes of the cranium may be preternaturally thin, without this being dependent on disease; but they are most obviously in that condition in hydrocephalus, in which affection, however, there are two opposite states of the skull.

When the disease occurs in infancy, and persists for any length of time, the bones of the calvaria usually become thin and pellucid; the spaces between them are of great extent; and the deposition of the inorganic texture is arrested in such a way that instead of bones we have frequently little more than a membrano-cartilaginous lamina, and sometimes not even that; for instances have been known in which the upper part of the head has been covered by membrane only. This suspension of action, however, is in some instances only temporary. The deposition of ossific matter becomes then more rapid and abundant than under ordinary circumstances; the points of deposit are more numerous than usual; and a skull of gigantic dimensions and of peculiar and premature hardness is produced.

It has been sufficiently explained that the several ossific elements of the cranium unite in definite numbers to produce the bones which we have been occupied in describing. Nevertheless, it not unusually happens that some of these elements, or, otherwise, adventitious deposits of a similar character, which manifest themselves, do not flow into and combine with the other elements of the bone in which they occur; but, on the contrary, each in itself forms the centre of an ossific process, and the bone thus formed (be it large or small) articulates by its circumference to the parts with which it comes into contact. These adventitious pieces are commonly known under the name of *ossa Wormiana*, because it is supposed that they were first described by Wormius, a physician at Copenhagen in the seventeenth century;* they are also called *ossa triquetra, triangularia, ossa suturarum, ossa supranumeraria.* They vary in situation, number, and size. In general they are situated in the lambdoidal suture; they are, however, met with in the sagittal, occasionally in the coronal, and (though rarely) in the squamous suture. One of the most remarkable is that which sometimes replaces the superior angle of the occipital bone, called by Blasius *os triangulare* or *epactale.* Bertin describes one in the situation of the anterior fontanelle.

It is by a process analogous to the preceding that the occipital bone occasionally presents a suture between the upper and under halves of its posterior portion. The elements of those two parts combine among themselves, and the pieces resulting from their union approach, and, instead of forming the continuous bone, as we usually see it, they are associated by means of an additional suture.

An anomaly of not very unusual occurrence is the permanence of the suture uniting the two halves of the frontal bone, and which is seldom apparent beyond the second year of extra-uterine life.

* Vid. Ol. Wormii et ad eum doctorum virûm epistolæ, t. i. Hafniæ, 1728.

There are but few skulls which are perfectly symmetrical, although the variation of one side from the other is generally so slight that the eye does not at once detect it. In numerous cases, however, the want of symmetry forcibly obtrudes itself; sometimes one half is considerably larger than the other; and in other cases it appears to be thrown out of position, as though, during the time that the parietes were soft, pressure had been applied in front and behind, and, by a sort of rotatory movement, it had been drawn back on one side and pushed forward on the opposite. There does not appear to be an absolute uniformity among the skulls of this description saving that the projections are always situated diagonally with respect to each other; that is, if it be twisted to the right, the right half of the frontal bone will be in advance of the left; while the posterior part of the left parietal, and the corresponding side of the occipital bone, will project behind the right. This is by far the most prevalent variation, but, occasionally, the left half of the frontal bone is in advance, and, in such instances, the posterior increase will be on the right side.

The change which takes place in advanced age can scarcely be accounted an anomaly. At that period the skull is much more an entire bone than it is in the earlier epochs. The sutures are to a certain extent effaced, and a mere line indicates the former disjunction of the bones. It is on the interior of the skull that these sutures are first effaced, and on the exterior the order of obliteration is from the summit to the base. It has been affirmed that the volume of the skull diminishes in old age, and that it is susceptible of change, in different directions, after the bones are locked together. It is, however, certain that its external configuration is somewhat altered, for the prominences formed by the centres of ossification of the parietal and frontal bones become flattened and undistinguishable from the rest of the parietes; which, as old age sets in, become thinner than they were previously. This change, however, is but temporary, for, in extreme old age, the skull is thicker and more porous than at any antecedent period of life. This hypertrophy is produced by the recession of the inner from the outer table, and the conversion of some part of the substance of each into a thin spongy tissue; the diplöe itself sustaining an analogous alteration, by the enlargement of its cells, and the thinning of the plates which form their walls.

Occasional instances occur in which the skull is of inordinate thickness, and this, apparently, without its being connected with the age of the subject. The late Mr. Joshua Brookes had some sections of a skull, found in a churchyard in Lancashire, of nearly three quarters of an inch in thickness; and specimens have been seen of more than an inch. In some of them the diplöe is perfect, the augmentation being in the two tables; in others, and indeed in the majority of specimens, the two tables and the diplöe are confounded together in one thick mass of matter, which is of an ivory hardness. It is not improbable that we might justly refer this condition, as well as some other peculiarities of the cranium, to inflammation of the bone itself, or of its investing membranes. That exostosis is the product of a limited periostitis admits of but little dispute, and it is very likely that those cases of hyperostosis in which there is a uniform deposit of bone, only mark the effect of a more diffused and general inflammation; the more so, since we meet with these local and general deposits, as well on the inner, as on the outer table of the skull, and for the existence of which it would otherwise be impossible to account.

When they occur on the inner table, the functions of the brain are usually more or less disturbed, although it would appear that the mental manifestations are not always implicated. In the skull of an idiot of advanced age, examined several years since by the writer of this article, there was a uniform deposition to the extent of nearly a quarter of an inch; and in a recent autopsy of a young girl, he found the entire syncipital region very irregular in its surface, from being studded with variously-sized nodules, the bases of which flowed into and were lost in each other. This girl was of feeble intellect, and the victim of epilepsy. In the examination of a body at the Hôtel Dieu, by Mr. King, that gentleman discovered on the petrous portion of the temporal bone a tumour which he had not been led to expect by any indication of suffering which appeared during life This tumour had the volume of a marble or pistol-bullet, was cellular in its structure, and perfectly smooth on its surface; a depression exactly corresponding to it was found on the under surface of the middle lobe of the brain, but its substance and membranes had their normal characters.

The cranium is oftentimes found in the opposite state of atrophy, in which the balance between deposition and absorption seems to have been disturbed, so much to the prejudice of the former, that the walls are sometimes not much thicker than a piece of paper. Whenever the two textures maintain their usual proportion, this atrophy may be regarded as a natural abnormal state; but those cases in which either the inorganic or animal element preponderates, and a fragility or softening of the bone is thereby established, must be referred to some constitutional affection in which the rest of the osseous system has participated, and the influence of which it will not fail to exhibit.

In addition to exostosis and hyperostosis, the cranium sustains other pathological changes as the effects of inflammation.

Previously to the establishment of osteitis, whether from a common or specific cause, mercurial or syphilitic, there is found that stasis of the blood which always precedes inflammation. The sanguineous complexion of the diplöe in cases of erysipelas testifies that this engorgement may be produced by increased action in the neighbouring teguments.

It has already been stated that hypertrophy of the cranium may be regarded as a termination of osteitis. When inflammation is limited in its action and of long duration, it is probable that the ossific element is poured into the cells of the diplöe so as to effect their obliteration; but when it is of a more vivid character, the opposite effect of softening (the precursor of ulceration) takes place, and both the outer and inner tables are rendered friable. This frequently occurs to a great extent in the mastoidal cells, especially in children; and as, in them, the posterior portion of the meatus auditorius internus possesses an unclosed fissure, the discharge which is consequent on the destruction of the cells is allowed an exit, before the membrana tympani is destroyed; although that, as well as the whole of the internal ear, is frequently involved in the ravages of the disease—then, however, having passed into another termination of osteitis, viz. ulceration.

Adhesion can take place only where the cranium has experienced a lesion from a mechanical cause; and it is altogether prevented if the solution of continuity be great. The edges of a wound, produced by a cutting instrument penetrating more or less perpendicularly to the surface of the bone, do not approximate; but they are united by an interposing callus as in the case of a common fracture, and the line formed by it is always visible in the same way as the cicatrix which persists after the adhesion of soft parts. When a piece of the outer plate is elevated by a cutting instrument passing very obliquely to the surface of the bone, and the scalp is not detached, it will, on being immediately re-applied, unite with the surface from which it has been raised; and, if it be altogether removed, the reparation will be effected in the same way as in other parts, viz. by the granulation and cicatrization of the cut surface.

When there is loss of substance of the entire thickness of the bone, whether that loss be produced by mechanical or pathological causes, granulations spring up from the dura mater; the edge of the opening becomes very thin; the surface cicatrizes and produces the appearance of a dense fibrous membrane, the circumference of which is attached to the margin of the hole and the adjacent pericranium.

Caries, which is analogous to ulceration of the soft parts, and is, in fact, an ulcerative absorption of bone, attacks the cranium in common with the rest of the osseous system; but it always first appears on one of the two tables, and not on the diplöe, although ultimately the entire thickness is, in some cases, involved. Indeed, when it commences on the inner table, it is only by the extension of the ulcerative process through the substance of the bone, that the suppurative collection can be emancipated.

In this affection the pericranium is sometimes enormously thickened and almost inseparably attached to the rough biscuit-like surface of the bone beneath. In other cases, especially in those in which the ulcerative process has been provoked by mercury, it is in irregular patches; the pericranium is unattached and the denuded surface is of a dark colour.

Necrosis, or mortification of the bone, is of frequent occurrence; but not in the way usually implied by that term. Whether it be the substance of the bone, or merely its outer lamina which is deprived of its vitality, the reparation is not by a fresh deposition of bone, nor is it coeval with the separation of the necrosed part, as in the long bones; but it is a subsequent action (such as has been already pointed out) which is established to supply the loss. Considerable portions of the frontal and parietal bones may thus be thrown off and the deficiency provided for by the granulations of either the subjacent diplöe or the dura mater.

Medullary sarcoma sometimes manifests itself in the cranium. It appears to commence in the diplöe by a deposition of tuberculous matter, which softens, and which in that state may be mistaken for pus; the inorganic element is withdrawn; the accumulation continues and advances towards both tables, which in turn submit to the same change of structure; and, ultimately, a tumour is formed, the capsule of which is constituted, on the one side by the pericranium, and, on the other, by the dura mater. In this tumour the knife detects spiculæ of bone interspersed throughout its substance, and the edge of the opening which is left in the skull after maceration, is studded with irregular projecting points.

For the Bibliography, see OSSEOUS SYSTEM.

(J. Malyn.)

CRANIUM, REGIONS AND MUSCLES OF THE, (Surgical Anatomy.)—If a line be drawn on the skull from the external angular process of the frontal bone, backwards along the rough line on that and the parietal bone, which indicates the attachment of the temporal fascia, be continued downwards and backwards parallel and a little external to the occipito-mastoid suture, and then be carried forwards along the inferior surface of the occipital bone to end just behind the foramen jugale, and a little internal to the stylo-mastoid foramen,—this line, with another similar one on the other side, will include an oblong region which has very natural limits both before and behind. Anteriorly this region is limited on each side by the anterior margins of the roof of the orbit, in the centre by the line of articulation of the frontal bone with the nasal and superior maxillary, posteriorly by the superior curved line of the occipital bone, and on each side by the mastoid process. To this oblong region may be appropriately given the designation *occipito-frontal region*.

The line which thus limits laterally the region just named circumscribes another region which occupies nearly the whole lateral surface of the cranium, and which is called the *temporo-parietal region*. This region passes into the base of the cranium, and may be limited below and within by a line from the styloid process external to the glenoid cavity, as far as the spheno-maxillary fissure *

* Blandin makes five cranial regions—*occipito-frontal, temporal, auricular, mastoid,* and the region of the *base* of the cranium: the last is quite out of the reach of the surgeon, and therefore is excluded from consideration in the present article. Velpeau has three regions,—the *frontal, temporo-*

I. *Occipito-frontal region.*—The anterior and posterior boundaries of this region are sufficiently obvious on the integuments, the eyebrows forming the anterior, the posterior being constituted by a line extending as far as the mastoid process on each side of the occipital protuberance corresponding to the insertion of the superficial muscles of the back of the neck, which protuberance can be felt through the integuments. The lateral limits, however, are not so distinct; in the living subject, however, when the temporal muscle is rendered tense, a distinct line of demarcation is felt along the upper margin of this muscle, extending downwards and backwards nearly as far as the mastoid process.

We proceed to examine the several structures which are presented to the anatomist as he pursues the dissection of this region.

1. *Integument.*—It is in this region that we can best examine the general characters of the integument of the cranium, commonly known under the name of scalp (Fr. *cuir chevelu*). The greatest part of it is remarkable for the more or less luxuriant growth of hair from it,* the nature of which, it is hardly necessary to observe, differs materially in the male and in the female. In the natural state about two-thirds or three-fourths of the scalp are covered with hair, the anterior third or fourth,—namely, the skin of the forehead,—being uncovered. In front the hairs terminate abruptly on the frontal region; behind they terminate less abruptly, and descend in general to a variable distance on the posterior part of the neck, becoming finer and more downlike as they descend. The natural direction of the hairs is at right angles with that portion of the scalp from which they grow; consequently the difference of direction of the hairs depends upon the differences in the aspects of those regions. This is most obvious in that part of the head which is called the crown, which in most persons inclines downwards and backwards to a greater or less extent. Such, however, is the influence of art in the arrangement of the hair, that it is difficult to meet with "a head of hair"—to borrow the phrase from the hair-dresser,—where the growth is perfectly natural.

There is an obvious difference in the nature of that portion of the scalp from which hairs grow, and that which is naturally bald: the former is much thicker and denser, owing, no doubt, to a larger developement of the fibres of the corion, and to the great magnitude of the hairs which pierce it. It is at the posterior part of the occipito-frontal region that the hairs are strongest, and that portion of the scalp very rarely becomes bald.

2. *Subcutaneous tissue.*—Subjacent to the integument is a dense and lamellated cellular tissue, with little fat, and such as does exist deposited in small pellets, much more numerous in the posterior part of the region. This cellular membrane is very intimately connected with those parts of the scalp especially from which hairs grow; it is much more loose and less adipose in the frontal region; it also adheres pretty closely to the subjacent aponeurotic expansion of the occipito-frontalis muscle. The bulbs of the hairs are lodged in it. The firm adhesion of this cellular membrane on the one hand to the skin, and on the other to the subjacent aponeurosis, is sufficient to account for the great pain and danger which attend punctured wounds of the scalp, in consequence of the non-extensibility of the membrane and the tension which a very slight degree of swelling consequently gives rise to.

3. *Muscles.*—If the scalp and subcutaneous tissue be divided by a transverse incision over the vertex, and the flaps carefully dissected off, —one as far as the eyebrows, the other to the superior curved line of the occipital bone, the occipito-frontalis muscle is brought into view. Anteriorly and inferiorly we find the few fibres of the orbicularis palpebrarum muscle overlapping the occipito-frontalis just above the margin of the orbit.

Occipito-frontalis (*epicranius*, Albin.: described by some anatomists as two distinct muscles, the *frontal* and *occipital*).

This is an expanded digastric muscle occupying the whole of this region. The two bellies of which the muscle is composed are united in the centre by a broad aponeurotic expansion. The anterior belly corresponds to a great part of the frontal bone, and the posterior to a part of the occipital. Very frequently the fibres are weak and pale, so that the dissector finds it difficult to trace out the extent and attachments of the muscle; and, moreover, even in its most developed state it is a thin muscle, so that great care is required for the accurate dissection of it.

The anterior belly of this muscle, or that which is by some called the frontal, consists distinctly of two lateral portions united by a narrow triangular slip of aponeurosis. Each portion is connected inferiorly to the integument of the eyebrow through the intervention of cellular membrane, and slightly overlapped by the superior fibres of the orbicular muscle of the eyelids, and commingled with some of the

parietal, and *occipito-mastoid*. The advantages to be derived from the subdivision of the body into so many small regions as is adopted by the French anatomists, are by no means obvious. I decidedly prefer a subdivision which is indicated by certain naturally prominent points or landmarks, which will, I think, in general be found to map out regions not too limited nor too numerous, nor yet too comprehensive.

* We cannot resist the temptation of transcribing the following passage from Gerdy, which is not devoid of some national characteristics. "La surface supérieure de la tête est arrondie et ovoïde. Elle est couverte par les cheveux qui en cachent les formes, lui donnent, par la soupplesse et le contraste de leur couleur, une sorte de beauté difficile à exprimer, et fournissent au gout delicat des femmes l'ornement le plus gracieux et le plus seduisant par les masses legères, les guirlandes flexueuses, les boucles arrondies qu'elles en composent, et par les mille arrangemens que suggere à leur imagination l'amour ou l'art de plaire. Mais la tête, se depouillant avec l'âge, de la chevelure qui l'embellisait, ne presente plus dans la vieillesse qu'une surface nue et luisante, ou l'on entrevoit quelquefois la trace des sutures frontales et parietales."

fibres of the last named muscle, as well as of the corrugator supercilii. The aponeurotic slip before alluded to, situated in the middle line, forms the internal boundary of each lateral portion. On the outside the fibres gradually shorten and extend a very short distance into the temporal region, over the temporal fascia. Each portion presents a convex margin above, which is inserted into the thin tendinous aponeurosis, which extends over the middle portion of the occipito-frontal region, corresponding to the posterior margin of the frontal bone, the fronto-parietal suture, internal portions of the parietal bones, the sagittal and lambdoidal sutures and part of the occipital bones, but separated from them by the pericranium and by some fine cellular tissue which connected the aponeurosis to the last-named membrane. This aponeurosis is called the *cranial* or *epicranial* aponeurosis: in some instances its fibrous character is very distinct in all its extent; but very frequently it is most manifest in its posterior third or half, the anterior part being little more than condensed cellular membrane, excepting near to the fleshy fibres of the frontal portion of the muscles, where the aponeurotic structure again becomes manifest. On the sides this aponeurosis gradually degenerates into cellular membrane without leaving any defined margin. The aponeurosis in its whole extent adheres closely to the superjacent subcutaneous cellular tissue and to the subjacent pericranium through the intervention of a fine cellular membrane already referred to. Proceeding from before backwards, we find that this aponeurosis ends in affording insertion to the fibres which form the posterior belly of the muscle.

This portion of the muscle, also called the *occipital* muscle, consists likewise of two lateral portions which are attached inferiorly to the external part of the superior curved line of the occipital bone, and to the mastoid portion of the temporal. The fibres are parallel and nearly vertical, inclining a little inwards, and are inserted, as already described, into the posterior margin of the epicranial aponeurosis. The attachment of the muscle to the occipital bone is immediately above that of the sterno-mastoid and splenius muscles. On the sides the fibres gradually disappear over the mastoid portion of the temporal bone, and the fleshy belly of the muscle lies immediately over the pericranium, some cellular membrane only intervening; its adhesion to the skin, however, is less intimate than that of the frontal portion.

This muscle is evidently destined to act upon the integuments of the cranium: its influence is most apparent upon the skin of the forehead and eyebrows; it distinctly raises the latter, and throws the former into transverse wrinkles. Under its influence the whole scalp may be made to move backwards and forwards, but the occipital portion of the muscle cannot create, as the frontal does, wrinkles in its corresponding integument, owing to the less firm adhesion of the muscle to it.

Subjacent to the anterior portion of the occipito-frontalis is the *corrugator supercilii* muscle. It lies on the inner half or third of the orbital margin of the frontal bone. By its inner extremity it is attached to the internal angular process of the frontal bone; the fibres pass thence outwards, inclining a little upwards, and are inserted into the integument of the eyebrow, being mixed with the orbicularis and occipito-frontalis muscle. This muscle evidently can depress the eyebrow, and acting in conjunction with its fellow, throw the integuments into vertical wrinkles, approximating the eyebrows, and occasioning the act of frowning. This muscle lies on the supra-orbital nerve and vessels.

4. *Nerves.*—The anterior part of the occipito-frontal region is freely supplied with nerves from those branches of the ophthalmic portion of the fifth which originate within the orbit. Of these the supra-orbital is the largest: immediately after its emergence from the supra-orbital foramen this nerve divides into a series of branches which pass up on the forehead, some adhering to the pericranium, others distributed to the muscle, and others becoming subcutaneous. Here, too, we find ramifications of the supra-trochleator or internal frontal nerve, chiefly distributed in the internal portion of the muscle. At the external part of this frontal region we find some filaments of the portio dura. In the posterior or occipital region the principal nerves are derived from the cervical plexus; the auricular and mastoid branches of this plexus distribute their filaments here; and we also find ramifications from the posterior branch of the first cervical nerve, accompanying the subdivisions of the occipital artery.

5. *Arteries.*—In front we have ramifications of the supra-orbital and superficial temporal freely anastomosing with each other; and deeper-seated, a few branches of the deep temporal, distributed to the pericranium. In the occipital region we have the occipital, often of considerable size, and the posterior auricular also sends some of its ramifications to anastomose with the occipital branches. Both in front and behind, the arteries of opposite sides inosculate with each other on the middle line.

6. *Veins.*—Small veins accompany most of the arteries; but the most remarkable vein is one which is situated in the frontal region nearly on the middle line; it is the frontal vein, or *vena preparata*, sometimes replaced by two or three. Velpeau advocates the revival of the ancient practice of bleeding from this vein in head affections. It carries the blood, as he observes, from all the anterior part of the head to the root of the nose, whence he argues that venesection practised on this vessel would empty the whole of the scalp. How often in practice do we see manifest advantage from cupping the temples or some region of the scalp, when little or no benefit had been derived from other modes of practising the detraction of blood!

7. *Lymphatics.*—The lymphatics are very few, and pass into the parotid ganglions, or those behind the ear or in the superior part of the neck.

8. *Pericranium.*—This fibrous tissue, pos-

sessing the same properties as the periosteum in other parts of the body, is, in a practical point of view, not the least interesting structure which is to be found in this region. It is largely supplied with blood, more especially in early life. We have already noticed its adhesion to the superjacent aponeurosis; it adheres to the bone by cellular membrane, and is easily raised from it by dissection in all points except where there are sutures. This membrane is not unfrequently the seat of periostitis and of nodes.

II. *Temporo-parietal region.*—The lateral boundary of the occipito-frontal region constitutes the superior limit of this region, and a line drawn from the external angular process of the os frontis backwards and a little downwards along the zygoma to the mastoid process of the temporal bone, limits it inferiorly.

The integument and subcutaneous cellular membrane of this region differ but little from the same structures in the occipito-frontal region. The former is finer and not so thick as in the middle and posterior parts of the last-named region. The hairs are oblique, some directed forwards, others backwards towards the occiput, and others downwards overlapping the ears. Here the hairs first begin to grow grey, whence the denomination *tempora* has been applied to these regions, grey hairs marking the inroads of time. The skin of this region, however, is naturally bald for a considerable portion in front of the ear, and for the distance of about an inch immediately behind and above it.

The subcutaneous cellular tissue is very loose in front of the ear, but behind it in the vicinity of the mastoid process, it is more dense, and hence the scalp is much less moveable over that process, and immediately behind the ear. The epicranial aponeurosis is confounded with this subcutaneous tissue in the superior part of this region.

Temporal fascia.—Subjacent to the cellular expansion is a fibrous membrane of considerable strength, which stretches from the zygoma below to the curved line above and behind which limits the temporal fossa on the frontal, parietal, and temporal bones. It is very thick and strong, composed of white interlacing fibres, firmly attached to the points of bone referred to, and giving attachment by the greater part of its deep surface to the fibres of the temporal muscle. In front and below, however, for a short space, some adipose cellular membrane intervenes between the muscle and the fascia. Along the margin of the zygoma, especially in front, the fascia is divisible into two laminæ, which pass down, one internal, the other external to the bone, and become incorporated with periosteum: by their separation above the zygoma they leave a triangular space which is in general filled with cellular tissue more or less adipose.

Muscles.—Some fibres of the occipito-frontalis extend more or less into this region, according to the state of developement of the muscle. Here too we find the three auricular muscles immediately subjacent to the subcutaneous cellular tissue. (See Ear.) Under the temporal fascia and adhering to its deep surface is the fleshy portion of the temporal muscle, attached to almost the whole of the fossa. Behind, the mastoid process is enveloped by the tendinous insertion of the sterno-mastoid muscle.

Nerves.—The nerves of this region are very numerous. The subcutaneous ones are derived from the portio dura and the superficial temporal or auricular of the fifth, and posteriorly from the mastoid and digastric branches of the portio dura, as well as some from the ascending branches of the cervical plexus. The deep-seated nerves in the temporal fossa are the deep temporals from the inferior maxillary, and the temporal filament of the orbitar branch of the superior maxillary.

Arteries.—The superficial arteries are numerous and important. They are derived from the trunk of the superficial temporal, which enters this region by passing over the zygoma in front of the tragus, crossed over by the *anterior auris* muscle. After it has passed the zygoma it inclines forwards, and is a little more distant from the ear than when on the zygoma. In all this course it may be felt distinctly, although it is pretty firmly bound down by the subcutaneous tissue and epicranial aponeurosis, which are here conjoined. A little more than an inch above the zygoma it divides, and we trace its anterior branch forwards towards the frontal region, which it enters and anastomoses with the supra-orbital. The posterior branch passes upwards and backwards, winding over the ear, and anastomoses with ramifications from the occipital artery. It is in one or other of these branches that arteriotomy is generally performed, in preference to opening the trunk of the artery. The middle branch of the temporal artery pierces the fascia, and enters the substance of the temporal muscle, anastomosing with the deep temporals. The posterior part of this region is supplied from branches of the occipital and posterior auris.

Veins.—Veins accompany almost all the arteries: there are none worthy of any special notice.

Lymphatics.—These vessels likewise accompany the arteries, and enter the ganglions in the neighbourhood of the ear, and those of the neck.

Pericranium.—The pericranium does not differ from that of the occipito-frontal region, except perhaps in firmer adhesion to the squamous portion of the temporal bone. It affords insertion to the fibres of the temporal muscle. This region presents more surgical interest than the former one; it is more frequently the seat of operation (arteriotomy, and in its posterior part, that of opening the mastoid cells); and in consequence of the number of its arteries and nerves, and the great strength of the temporal fascia, wounds in this region are of a more dangerous kind. Fractures here are also liable to be complicated with a wound of the middle meningeal artery, part of the course of which corresponds to this region.

(R. B. Todd.)

CRUSTACEA. Eng. *Crustaceans;* Germ. *Krustenthiere;* Fr. *Crustacés*—This is the name given to a class of articulated animals, the type of which we have in the common crab and lobster, and which is essentially distinguished by the conformation of the organs of circulation, of respiration, and of locomotion.

The body of these animals is *articulated;* that is to say, it is divided into rings, for the most part very distinct and partially moveable; their integuments are of considerable consistency, being either horny or calcareous, and form a kind of external skeleton; their extremities are also articulated, arranged in a double series, and constitute antennæ, jaws, limbs, (ambulatory, natatory, or prehensile, the most common number of which is five or seven pairs,) and other appendages; their nervous system is ganglionic, situated partly in front of the alimentary canal, and partly behind and below the intestine; their blood is colourless, and put into motion by an aortic and dorsal heart; their respiration is almost invariably aquatic, and is accomplished by means of branchiæ, or the skin only; to conclude, the sexes are distinct, and the organs of generation double.

Great and striking analogies occur between the Crustacea, the Insecta, and the Arachnida; so that it was long the custom to associate the whole of the animals now comprised in these three classes, under the single name of INSECTA, or Insects. Brisson and Lefranc de Berkhey proposed, it is true, to separate the Crustacea, but the classifications of these writers not being based upon organic characters of sufficient consequence, did not receive the general assent of naturalists, and it is only since the beginning of the present century that the necessity of separating the annulosa into certain distinct classes has been universally acknowledged. This result was mainly due to the anatomical inquiries of Cuvier, and this great naturalist was even the first who established a class among the invertebrate series of animals for the reception of those having bloodvessels, a ganglionic spinal cord, and articulated extremities, characters which, at the present time, still suffice to distinguish the Crustacea from the greater number of other animals.

It is more especially in the general conformation of the body, in the structure of the extremities, and in the organization of the nervous system, that the Crustacea resemble the Insects and Arachnidans. The apparatus of vegetative life in these different animals presents numerous and important differences. Thus Insects, instead of breathing by means of branchiæ, and possessing a vascular system like the Crustacea, breathe by means of tracheæ, and have no bloodvessels; and Arachnidans, which, like the Crustacea, have a heart more or less perfect, and distinct vessels for the circulation of their blood, have an aerial respiration effected either by the medium of tracheæ or of pulmonary sacs.

The whole of the Crustacea are evidently formed after one and the same general type; still, numerous and extensive varieties of structure are observed among these animals; and when compared one with another, their organization is found to become more and more complicated in proportion as we rise in the series comprised by the group; it is farther found that the lower links of this kind of chain represent, to a certain extent, the different phases through which the more perfect Crustaceans pass during the period of their embryonic existence.

This diversity of organization affords the grounds by which naturalists are guided in their distribution of the Crustaceans into orders and families.

The natural arrangements of these animals that have been followed, are consequently observed to vary with the extent of knowledge of their structure possessed. It were tedious to enter upon the consideration of the different systems which have been successively proposed for their classification; in order to aid the mind in the comprehension of the anatomical details into which we shall have to enter in the course of this article, it will be enough for us to present at once those divisions which appear to indicate most truly the differences and resemblances subsisting between the various members of the class;* and to do this in the most compendious manner, and to exhibit the classification which thence ensues, we shall present them to the reader in the shape of a synoptical table.

* See Histoire Naturelle des Crustacés, par M. Milne Edwards, vol. i. p. 231.

ORDERS.

Class	Division	Section	Legion	Characters	Order	Characters	Tribe	Genera
CRUSTACEA	1st Division. The mouth furnished with a certain number of organs, destined in an especial manner to the prehension or division of the food.	MAXILLOSA seu MANDIBULATA mouth armed with jaws, &c.	PODOPHTHALMIA.	Almost always with branchiæ, properly so called. Eyes pedunculated, and moveable. Extremities (feet) constantly vergiform, and in general partly prehensile, partly ambulatory. Thorax covered by a carapace.	DECAPODA	Branchiæ fixed to the sides of the thorax, and enclosed in special respiratory cavities. Oral apparatus composed of six pairs of members. Five pairs of thoracic extremities, generally ambulatory.	Brachyura	Cancer, Portunus, Podophthalmus, Thelphusa, Gecarcinus, Grapsus, Ocypode, Pinnotheres, Maja, Leucosia, Dorype, &c,
							Anomoura	Dromia, Ranina, Hippa, Remipes, Pagurus, Birgus, &c.
							Macroura	Astacus, Scyllarus, Palinurus, Palemon, Penœus, &c.
					STOMAPODA	Branchiæ external; sometimes rudimentary or none. Oral apparatus composed in general of three pairs of members. Thoracic extremities prehensile or for swimming; generally six or eight pairs.		Mysis, Thysanopodes, Cynthia, Phyllosoma, Alima, Squilla.
			EDRIOPHTHALMIA.	Branchiæ, properly so called, none, but replaced by certain portions of the extremities modified *ad hoc* in their structure. Eyes sessile. Thoracic extremities ambulatory, almost always consisting of seven pairs; no carapace.	AMPHIPODA	Palpi of the thoracic extremities vesicular, and subserving respiration. Abdomen very much developed, subserving locomotion, and furnished with six pairs of limbs, the three first of which differ in form and use from the three last.		Gammarus, Talitra, Hyperia, Phronima, &c.
					LÆMODIPODA	Abdomen rudimentary. Palpi of the thoracic extremities vesicular and subserving respiration.		Proto, Caprella, Cyanus, &c.
					ISOPODA	Abdominal extremities well developed; the five first pairs lamellar and subserving respiration. Abdomen well developed.		Idotea, Spheroma, Cymothoa, Jona, Bopyrus.
			BRANCHIOPODA...	No branchiæ, properly so called, but thoracic extremities lamellar, membranous, and so formed as to be subservient to respiration.	PHYLLOPODA	No bivalve shell-like covering. Extremities natatory and in considerable number (from eight to twenty-two).		Branchipus, Limmadia, Nebalia, &c.
					CLADOCERA	Carapace in the form of a bivalve shell. Thoracic members five pairs.		Daphnia, &c.
			ENTOMOSTRACA...	No branchiæ, nor any modification of organ apparent to supply the place of these. Eyes sessile, and commonly united into a single mass.	COPEPODA	Body divided into distinct rings, neither carapace nor valvular envelope. Thoracic and oral members in considerable numbers.		Cyclops, Pontia, &c.
					OSTRAPODA	Body without very evident annular divisions, and entirely enclosed under a large dorsal shield, having the form of a bivalve shell. Extremities in very small number.		Cypris, &c.
		EDENTATA seu HAUSTELLATA		Mouth prolonged in the shape of a sucker	ARANEIFORMES	Extremities rod-like, long, adapted for walking....................		Pycnogonon, Nymphon.
					SYPHONOSTOMATA	Extremities not adapted for walking, partly lamellar, partly prehensile.		Caligus, Dichelestion, Nicothoa, &c.
					LERNÆIFORMES	Extremities rudimentary, body presenting anormal forms		Lernæa, &c.
	2d Division.—The mouth unfurnished with special prehensile or masticatory organs, but surrounded by ambulatory extremities, the bases of which perform the part of jaws.				XYPHOSURA	....		Limula.

§ 1. *Of the skin or tegumentary skeleton, and of the organs of locomotion.*

In the definition which has been given of the Crustacea, one of the most important characters was derived from the nature and disposition of their tegumentary system. And it is from this point that we shall start in laying before our readers a detailed account of the peculiarities of organization presented by this class of animals. By pursuing this course all the subsequent parts of the present article will appear clearer, the disposition of the internal organs, their forms, their mutual relations, &c. being in a great number of instances readily explicable by the various modes of conformation of the modified skin, which in this class performs the important office of the internal skeleton among the Vertebrata.

In some Crustacea the skin always continues soft, but in the greater number it presents a great degree of solidity, and forms a solid casing, within which are included the whole of the soft parts. This difference in the condition of the tegumentary envelope is generally found to coincide with the presence or absence of particular organs for the purposes of respiration; and in fact it is easy to understand that in those species in which this important function is performed by the surface of the body at large, the integument required to be membranous, whilst in those in which the covering is of stony hardness, a condition which renders it incompetent to expose the blood to the contact of the atmospheric air dissolved in water, respiration can only be performed by the medium of organs especially contrived and set apart for the purpose.

When the tegumentary envelope of the Crustacea is studied among the more elevated individuals of the class, it is found to possess a somewhat complex structure; parts may be distinguished in it comparable to those which are known to constitute the integument of the Vertebrata. Among the *Brachyura*, for instance, the integument consists of a *corium* and an *epidermis* with a *pigmentary matter* of a peculiar nature destined to communicate to the latter membrane the various colours with which it is ornamented.

The *corium* or *dermis*, as among the Vertebrata, is a thick, spongy, and very vascular membrane; on its inner surface it is intimately connected with a kind of serous membrane, which lines the parietes of the cavities in the Crustacea in the same manner as the serous membranes line the internal cavities among the Vertebrata; these two membranes, divided in the latter order by the interposition of muscular and bony layers, which cover and protect the great cavities, become closely united when these layers disappear, as they do in the Crustacea in consequence of the important changes that take place in the conformation of the apparatus of locomotion.

The *corium*, again, among the Crustacea, is completely covered on its outer surface by a membranous envelope unfurnished with blood-vessels, and which must be held in all respects as analogous to the epidermis of the higher animals. It is never found in the properly membranous state, save at the time of the Crustacea casting their shell; at this period it is interposed between the corium and the solid covering, ready to be cast off, and has the appearance of a pretty dense and consistent membrane, in spite of its thinness. It forms, as among animals higher in the scale, a kind of inorganic lamina, applied to the surface of the corium, from which it is an exudation. After the fall of the old shell, it becomes thicker and very considerably firmer, owing to the deposition or penetration of calcareous molecules within its substance, as well as by the addition of new layers to its inner surface. The degree of hardness finally acquired, however, and the amount of calcareous matter deposited within it, vary considerably; in many members of the class it remains semi-corneous, in a condition very similar to that of the integuments of insects, with which, moreover, it corresponds very closely in point of chemical composition; in the higher Crustaceans, again, its composition is very different: thus, whilst *chitine* in combination with albumen is the principal element in the tegumentary skeleton of some species, this substance scarcely occurs in the proportion of one or two-tenths in the carapace of the *Decapods*, which, on the contrary, contains sixty and even eighty per cent. of phosphate and carbonate of lime, the latter substance particularly occurring in considerably larger proportions than the former.*

With regard to the *pigmentum*, it is less a membrane or reticulation than an amorphous matter diffused through the outermost layer of the superficial membrane, being secreted like this by the corium. Alcohol, ether, the acids, and water at 212° Fahr. change it to a red in the greater number of species; but there are some species in which it may be exposed to the action of these different agents without undergoing any perceptible change.†

The epidermic layer hardened in different degrees is the part which mainly constitutes the *tegumentary skeleton* of the Crustacea. In its nature it is obviously altogether different from that of the internal skeleton of the Vertebrata; still its functions are the same, and this physiological resemblance has led naturalists to speak of these two pieces of organic mechanism, so dissimilar in their anatomical relations, under the common name of *skeleton*.

The tegumentary skeleton of the Crustacea consists, like the bony skeleton of the Vertebrata, of a great number of distinct pieces, connected together by means of portions of the epidermic envelope which have not become hardened, in the same way as among the higher animals certain bones are connected by cartilages, the ossification of which is only accomplished in extreme old age. On the varieties which these pieces present in their

* Chevreul and Geoffroy, Journal Complémentaire du Diction. des Sciences Médicales, Avril 1820. Milne Edwards, Hist. Nat. des Crustacés, t. i. p. 10.

† Lassaigne, Journal d. Pharmacie, t. vi. p. 174.

number, their form, their relations, &c. depend the differences that occur in the conformation of the solid frame-work, the anatomical study of which is now about to engage our attention.

The most prominent feature in the external skeleton of the Crustacea is common to the whole grand division of articulated animals, and consists in the division of this envelope into a series of segments or rings, connected in succession one with another, and supporting tubular appendages, also divided into segments, and arranged endwise. This peculiar structure is met with among the whole of the Crustacea; but when the frame-work of these animals is examined more narrowly, variations are discovered so extensive and so numerous, that the mind is almost led to regard it as consisting of elements essentially different. Yet this is not so; and in pursuing the study, aided by the means of investigation developed in the progress of the philosophy of the natural sciences, very opposite results are elicited,—results which are replete with interest and instruction in regard to the mysteries of nature in her creative energies.

Now these methods of investigation may be reduced to two:—the first, which studies creatures at their full growth, after having arranged them according to the natural order which follows from the investigation of their organization: the second, which studies each creature, but the more perfect in preference, in the series of successive evolutions which constitute the different phases of the embryonic state and of extra-uterine life; for it is a demonstrated fact that these two series, so distinct, so widely separated in appearance, are in reality connected by links so intimate, that the one is, in certain respects, the permanent reproduction of the other, which is the continual repetition of the first in one and the same individual.

By studying in this relative or comparative manner the skeleton of the Crustacea, we succeed in reducing to common principles the mode of conformation, apparently so various, of this apparatus, in the different groups formed by these animals. A remarkable tendency to uniformity of composition is every where recognizable, and all the varieties are explicable in a general way by the laws in conformity with which the development of these animals takes place.

During the period of embryonic life the body is seen becoming divided into rings more and more numerous, and more and more unlike one another. The same tendency to diversity in the organization is also found in the types of which the series of Crustaceans consists; and in both instances the differences are readily seen to depend on various modifications undergone by parts originally similar. It is farther referable to one of the most general laws of organization, viz. the tendency which nature shows to perfect functions by subdividing the work to be done, and throwing it upon a greater number of special organs. And we observe, in fact, among the most inferior animals that the different segments into which the body is divided are so completely repetitions of one another, that they all act precisely in the same manner; they severally include the elements necessary to the display of the vitality distinctive of the entire system to which they belong, so that they may be dissevered without any function whatsoever being therefore the less completely performed in either of the detached portions. Many Annelidans present instances of this uniformity of composition. As we rise, however, in the scale of beings, the different segments of the body are found to become more and more unlike, both as regards their functions and their conformation.

This law is also visibly manifested among the Crustaceans, whether they be studied at the various epochs of their embryonic state or compared together, examples being selected from the different groups of which this portion of the animal series consists. In either case a well-marked tendency to subdivision of the physiological operations is conspicuous; and in proportion as the divers acts, the aggregate of which constitutes the life of the individual, become attached to a particular system or place, the parts to which different functions are apportioned, acquire forms more dissimilar and more appropriate to their peculiar uses. When we come to treat of the evolution of the embryo of the Crustacea, we shall have occasion to revert to this subject, but it is necessary so far to hint at it in this place, inasmuch as the conclusions which have been mentioned will often supply us with means of explaining those difficulties that are encountered when we seek to render comparative the study of the different constituent parts of the external skeleton of the articulated series of animals.

The frame-work or solid parts of the Crustacea consist, as we have said, of a series of rings.

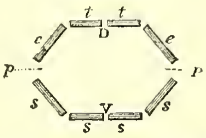
The number of these rings may vary, but this happens to a much less extent than on a superficial view we might be led to conclude. By calling in to our aid the principles of observation and of comparison pointed out above, we have found that in every member of this class of animals the normal number of segments of the body is twenty-one. But a very few instances of a larger number occurring are known, and it seldom happens that the number falls short of that which has been indicated. Occasionally, it is true, one or more rings prove abortive, and are never developed; but in general their apparent absence depends entirely on their intimate union one with another, and other obvious indications of their existence may be discovered. By-and-by we shall find that in the embryo these segments are formed in succession from before backwards, so that, when their evolution is checked, the later rather than the earlier rings are those that are wanting; and in fact it is generally easy to see in those specimens of full-grown crustaceous animals whose bodies present fewer than twenty segments, that the anomaly depends on the absence of a certain number of the most posterior rings of the body.

The Lœmodipods, the Entomostraca, and the Haustellate Crustacea present us with instances of this condition, which calls to mind one of the stages through which the embryo of the higher species, whose development is the most complete, is known to pass.

Each segment of the body, when it attains its normal condition, consists of two distinct elements: the central or annular portion, and certain appendices which it supports.

The central or annular portion of the segments of the tegumentary skeleton presents, in its most simple state, the appearance of a complete ring, but instead of a single piece it is requisite to count in its composition no fewer than eight, as has been demonstrated by the inquiries of M. Audouin on the structure of the thorax of insects,* inquiries the results of which are immediately and almost wholly applicable to the Crustacea so nearly allied to the insects in their organization. Each ring is divided first into two arcs, the one superior or dorsal, the other inferior or ventral, and each arc may present as many as four élementary pieces. Two of these pieces by being united in the me-

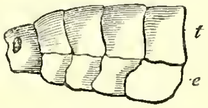
Fig. 378.



Theoretical figure illustrating the composition of the tegumentary skeleton of Crustacea.
D, Dorsal arc; *t, t,* tergal pieces; *e, e,* epimeral pieces; *V,* ventral arc; *s, s,* sternal and episternal pieces; P, insertion of the extremities.

dian line constitute the *tergum* (*fig.* 378, *D*); the superior arc is completed on either side by two other pieces, known under the name of *flancs* or *epimeral pieces* (*fig.* 378, *e*). The inferior arc presents in its composition an exact counterpart of the superior. Two of the four pieces into which it may be resolved constitute the *sternum*, situated in the median line, and are flanked by the two *episternums*. The two arcs thus composed, instead of cohering by their edges, leave a space for the insertion of the lateral appendages or *extremities* which corre-

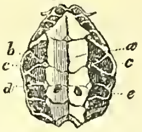
Fig. 379.



Anterior portion of the body of an Amphipoda.
t, tergum of the fourth thoracic ring; *e,* epimera of the same ring.

spond with them. It is true, indeed, that we have no instance of any single ring which exhibits the whole of these pieces distinct from one another; in general several are anchylosed so as to appear but one; yet the comparative study of the apparatus in the different members of the class at large, leaves no doubt of their existence severally.

Fig. 380.



Thorax of an Atelecyclus seen from below.
a, sternal pieces of the second thoracic ring; *b,* episternal piece of the corresponding ring; *c,* epimeral pieces; *d,* apodemata, which run from the sternum to the epimera, and separate the insertions of the extremities; *e,* antipenultimate ring of the thorax presenting the orifices of the female reproductive organs.

It frequently happens that the tegumentary membrane is folded so as to penetrate more or less deeply the interior of the ring among the different organs which fill the cavity. These folds, which may become solid laminæ by being impregnated with calcareous salts, have received the name of *apodemata*, and always proceed from the lines of conjunction of the different pieces, or of the different rings with one another. We shall have occasion to revert to this part of our subject very shortly.

Fig. 381.

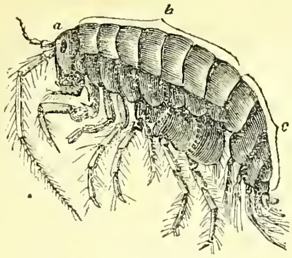
Thorax of the Maja Squinado, shewing the apodemata which form septa between the sternum and the epimeral pieces of the thoracic rings.

The structure of the ring once investigated in the manner we have done, let us now proceed to inquire in what manner the different rings by the modifications they undergo, and by the divers modes of union they present, give rise to the variety of forms we observe among the Crustaceans.

By general consent and usage, three regions are recognized in the bodies of these animals,—a *head*, a *thorax*, and an *abdomen;* and from this custom we shall not depart, although we must avow that these denominations are only derived from very clumsy views, and are calculated to convey false impressions in regard to the nature and composition of the parts so named, by leading the mind to liken them to the grand divisions entitled head, thorax, and abdomen in the Vertebrata. Nevertheless, with the exception of the objectionable names, the division of the body into three regions is not less a fact as regards the organization of the Crustaceans; and the one-and-twenty rings of which, as we have said, their body consists in the type to which every member of the class may be referred, are generally found divided into three

* Annales des Sc. Nat. tom. i.

Fig. 382.



Talitra Saltator magnified.
a, head; *b*, thorax composed of seven distinct rings; *c*, abdomen composed also of seven distinct rings.

equal series of seven, each of which may be held as corresponding with one of the three regions. This law of composition is observed to obtain not only among the more simple species, where the rings generally resemble each other most closely, but its influence may be remarked among the most complicated also, and amidst exceptions and contradictions in appearance the most obvious. The head or cephalic region includes the principal organs of sense as among the Vertebrata, the commencement of the apparatus subservient to digestion, and the appendages destined to seize and masticate the food. The thorax, strictly speaking, forms no cavity distinct from the preceding, but is its continuation; the part especially designated thorax, however, is that which is included from front to back between the head and the beginning of the abdomen, and is formed by the rings to which the extremities serving for locomotion are attached. This middle portion of the general cavity of the body contains almost the whole of the viscera. As to the abdomen, it succeeds the last of the thoracic rings, distinguishable by the presence in it of the orifices of the male organs of generation; the appendices attached to it do not commonly attain any considerable size, and do not serve in a general way as organs of locomotion; to conclude, nothing is found in its interior save muscles and the terminal portion of the intestinal canal, the anal orifice of which exists in the last of the abdominal series of rings.

These three portions of the tegumentary skeleton are not always equally distinct, and their respective limits may even vary, for we occasionally observe two or three of the foremost thoracic rings detaching themselves, as it were, from this region to which they properly belong, to join or blend with the cephalic rings; and the same thing may be said in regard to the segments of which each of the remaining divisions of the body consists; we in fact know of no specimen of a Crustacean in which the whole of the rings are moveable upon one another; a certain number of them always appear to become consolidated, and this union is frequently so intimate that all traces of its existence are obliterated, so that the section of the body which results from this aggregation of rings appears to consist of no more than a single piece, and on a cursory view might be held to be constituted by a simple ring. The shape and size of these compound rings varies also, circumstances which evidently depend on the unequal development of the different pieces of which they severally consist.

This consolidation of the rings occurs with increasing frequency as we rise in the scale of Crustaceans, and approach those the organization of which is most complex; yet there are a considerable number of species which form exceptions to this rule. The consolidation of the rings also shows a tendency to take place in the same order in which the different segments of the tegumentary skeleton appear in the embryo, that is to say from before backwards: thus it is generally complete as regards the cephalic rings; it is more frequent as regards the foremost than the hindmost thoracic rings; and it but rarely occurs among the abdominal rings.

The differences which present themselves in the dimensions and forms of the different rings of the tegumentary skeleton, and which concur so essentially in producing varieties in the general form of the Crustaceans, also show a tendency to become greater and greater as we ascend in the series of these animals, and commonly influence the cephalic rings in a degree greater than those of the divisions situated more posteriorly.

To conclude, it is also among the most elevated Crustaceans that the tegumentary skeleton is complicated in the greatest degree by the evolution of apodemata in the interior of the rings; and further, it is in the cephalo-thoracic portion of the skeleton only that these laminæ are encountered.

A few examples will render these general rules more readily appreciated.

In the earlier periods of evolution of the embryo of the river-crab, the whole of the rings, which are even then apparent, are of the same form and dimensions, and the segments, which only appear at a later date, are at first similar to what these rings were in the beginning. This state of uniformity in the composition of the whole of the constituent rings of the tegumentary skeleton, which is invariably transient in the embryo, is not observed as a permanent feature in any perfectly developed Crustacean; still there are several of these animals which are but little removed from it. In the Branchipods, for instance, the body consists of a long series of rings, having, with the exception of the very first, as nearly as possible the same form and the same dimensions. In the Amphipods (*fig.* 382) the want of resemblance between the different rings of the body becomes much more remarkable: the first seven become so completely united that they form a single piece, in which no trace even of the lines of consolidation remains, and the conical segment which constitutes the head grows much more slowly than the rest of the body, so that the relative dimensions become smaller and smaller as regards the head in proportion as the animal approaches the adult age. The seven rings of the thorax, on the other hand, continue perfectly distinct, and differ but little from one another; and the seven abdominal rings, in like manner, remain moveable, and only differ from those of the thorax as they do from one another by a relatively inferior degree of development. In the majority of the Isopods the structure of the tegumentary skeleton is essentially the same as in the Amphipods; but there occurs a greater inequality of development between the thoracic and the abdominal rings, most of the latter remaining more or less in a rudimentary state.

In the Apus and the Nebalia we continue to find the rings of the thoracic and abdominal portions of the tegumentary skeleton nearly equal in size and similar in form; but the cephalic section, instead of presenting the same conformation as these two portions of the body, constitutes superiorly an immense shield, which extends over the rings of the thorax and conceals them. This dorsal shield or buckler, which is denominated *Carapace* by zoologists, also occurs among the whole of the Podophthalmians, and more than all besides conspires to give to these animals their distinguishing peculiarities of shape. Inquiries, of which it would be tedious to give a detailed account in this place, have led us to discover that the carapace of these Crustaceans is neither more nor less than the superior arc of the third or fourth cephalic ring, enormously developed, and which in attaining its large dimensions laps over and modifies the conformation of a greater or smaller number of the neighbouring rings.*

In the generality of the Stomapods the carapace does not quite cover and conceal the two first cephalic rings, which indeed continue distinct and moveable; but in the whole of the Decapods these rings cohere with one another and with the following ones, and unite more and more intimately under the carapace, which then covers the whole of the head as well as the thorax. In the Macroura the anterior extremity of the carapace only extends over the ophthalmic or first cephalic ring; but in the Brachyura it bends around this ring so as to include it, and to go to unite underneath with the next segment. As we ascend in the series of Crustaceans, we observe the carapace encroaching more and more upon the thorax. In the Squillæ the three last cephalic and three first thoracic rings are nearly lost by becoming blended with those to which the carapace belongs; they scarcely retain any mobility, and protected above by this shield, unite intimately, and remain imperfect in their tergal portions; the four last rings of the thorax continue, on the contrary, free, and are in almost every particular similar to those of the abdomen. In the Mysis this union of the cephalic shield with the segments of the thoracic division of the tegumentary skeleton is carried further, for there are not more than two of these rings which remain distinct. But it is in the Decapods that the carapace attains its greatest development, and that its influence upon the evolution of the thoracic segments is carried the farthest.

In these animals the framework of the body does not appear at first sight to consist of more than two portions, the one anterior, formed by the carapace, and representing the cephalic and thoracic segments conjoined; the other posterior, formed by the abdomen. In reality, the first fourteen rings of the body are covered by this enormous buckler, and are so intimately conjoined as to have lost all their mobility; the whole of the thoracic segments thus hidden below the carapace, are connected with it in their superior part, they are only joined with one another underneath and laterally; and their tergal parts having, in consequence of this, become useless, are no longer to be found, being in some sort replaced by the great cephalic buckler; thus the whole of these rings, in conformity with this arrangement, are imperfect and open above.

Hitherto we have not been able to determine whether the carapace of the Podophthalmia is formed at the expense of the third or of the fourth ring of the tegumentary skeleton; but we have the strongest reasons to conclude that this buckler is neither more nor less than the dorsal arc of one or other of these cephalic rings, and not of the two conjointly. In fact we can here demonstrate a composition analogous to that which we have already pointed out as characteristic of every arc, whether superior or inferior, of the different rings in their state of complete development, to wit, a tergal portion and two lateral or epimeral pieces. In following the embryo of the River-crab in its progressive stages of development, Rathke* observed the carapace to be formed of three pieces, which at length became consolidated so as to form but one. In many of the Decapods it is even easy to perceive this structure or composition in the carapace of adults, inasmuch as there exist lines marking the conjunction, and accurately indicating the respective limits of the different pieces of which this great dorsal plate is composed.

The general form of the carapace depends in great measure on the relative development of these different pieces; in the Macroura the tergal portion of the carapace extends but a short way backwards, whilst the lateral or epimeral pieces reach as far as the beginning of the abdomen, and being no longer kept at a distance by the tergum, meet in the median line of the back, and are there conjoined. In the Brachyura, on the contrary, the tergal portion is that which is especially developed, so that it constitutes the whole of the upper part of the carapace, whilst the lateral pieces, thrust outwards and underneath, only form a narrow band above the bases of the extremities.

It is also in consequence of modifications analogous to those on which the existence of the carapace depends, that in other Crustacea the

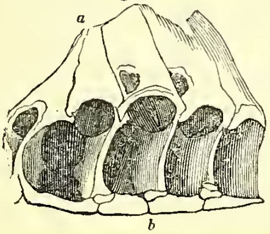
* See my Hist. Nat. des Crustacés, t. i. p. 23.

* Untersuchungen ueber die Bildung des Flusskrebses, &c. Tr. in Annales des Sciences Nat. t. 20.

tegumentary skeleton presents the most singular forms: thus among the Limmadia and the Cypris, the pieces which are analogous to the epimeral or lateral pieces of this cephalic buckler, acquire a great extension, whilst the tergal portion of the arc to which they belong continues rudimentary or proves entirely abortive, so that they constitute two large valves covering the whole body of the animal, and bearing considerable resemblance to the shells of certain acephalous Mollusks. The dorsal laminæ which in the Pandarus form appendices on the back similar to Elytra, and those which in the Anthostomata form a kind of sheath around the posterior part of the body, are also formed by the anomalous development of certain parts of both the dorsal and ventral arcs of the two posterior thoracic rings.

The inferior arcs of the thoracic rings of the tegumentary skeleton of the Decapoda, by their intimate union, form a kind of ventral shield, named *sternal plastrum*, upon which lines of conjunction indicate the respective limits of the greater number of the segments, as well as of the sternal and episternal pieces of which these are composed. In the Decapoda Macroura and Anomoura, this plastrum is in general very narrow, but in the Brachyura it is expanded to such a degree as frequently to constitute a great and nearly circular disc. In the whole of these Crustaceans, the lateral pieces of the thoracic rings are conjoined, like those of the inferior arc of the same segments, and form on either side of the middle portion of the body a septum which is covered by the carapace, and which is known among anatomists under the name of the *vault of the flancs*. In the Macroura this septum is nearly vertical, but in the Brachyura it is oblique, or even almost horizontal.

Fig. 383.

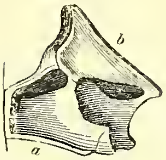


Lateral portion of the thorax of a Decapod.

a, the epimeral pieces united to form the vault of the flancs; *b*, the sternum; *c*, the apodemata rising from the sternum and separating the insertions of the legs.

It is among those Crustaceans the thoracic rings of whose tegumentary skeleton blend or become consolidated in this manner, and acquire dimensions so considerable, that the structure of this portion of the frame-work also exhibits the utmost extent of complication, in consequence of the existence of large *apodemata* in their interior. These septa are of two kinds; the one, styled *sternal apodemata*, arise from the lines of consolidation of the thoracic sternal pieces; the other, named *epimeral apodemata*,

Fig. 384.



Vertical section of a portion of the thorax of one of the Brachyura.

a, sternum, with a sternal apodema rising from it; *b*, epimera from the inner surface of which an epimeral apodema descends to join the sternal apodema, and thus form a septum between the thoracic cells.

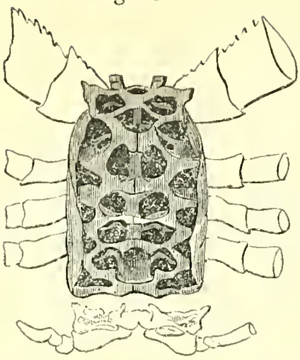
arise in a similar manner from the epimeral pieces of the same rings. They are met with among the Macroura and Anomoura, as well as among the Brachyura; but it is among these last that they acquire their highest development; their direction, vertical to the internal planes of the rings, and the unions of those that rise from the inferior aspect or floor with those that descend from the arched superior surface, give rise to the most singular combinations and forms, too multifarious to admit of description in an article of the extent of that in which we are engaged, but the final effect of which is the establishment of cells, divided from one another by vertical septa, and corresponding to each ring, and further intersected in the direction of their height, in a certain number of species, and divided into two stages by means of horizontal reduplications.

It is within these different cells that the muscles and principal vessels of the thorax are lodged in the Brachyura; holes left at the conjunctions of these laminæ admit of the communication of the cells two and two, either through the vertical septa or through the horizontal floors which divide the superposed cells, and it is by means of these holes of conjunction that the anastomoses of the vessels of one ring take place with those of the neighbouring ring, as we shall see presently.

In the Macroura, again, this structure does not occur, in consequence of which other means of communication between the vessels of the different segments require to be established, the nature of which we shall also have to investigate before long. Generally speaking, the disposition of these cells and of the septa which form them varies considerably in the Brachyura and the Macroura. Certain prolongations from the superior and internal angle of the sternal apodemata, by their union in the median line, after bending from before backwards, even form a longitudinal canal, which extends through almost the whole length of the thorax. This is the *sternal canal*, destined to lodge the ganglionic nervous cord, and to serve as the chief venous reservoir.

It has long been admitted as an axiom in animal physics, that when any particular part of the body acquires a very high degree of development, certain other parts stop short of their ordinary state of evolution, as if the former had obtained their unusual increment at the cost

Fig. 385.



Thorax of the Astacus Fluviatilis, showing the disposition of the apodemata and the thoracic cells.

of the latter. This rule, which has been discussed by M. Geoffroy St. Hilaire under the title of *la loi de balancement organique,* or law of organic equivalents, is found to apply in the present instance; for the Crustacea in which the cephalic portion of the tegumentary skeleton is developed in the greatest degree, (viz. the Brachyura) present the abdominal portion of the body of very small dimensions; whilst, on the other hand, in the Macroura, or those species in which the abdominal portion of the body arrives at its maximum of development, and performs a very important office in the business of locomotion, the cephalic portion is relatively greatly inferior in size.

With regard to its disposition the abdomen is simple enough; the rings of which it consists are in general moveable upon one another, and even when they are consolidated, present no apodemata projecting from their interior. It is also deserving of remark that the elementary pieces of the different rings are not very distinct, and sometimes even appear to be partially wanting.

Let us now go on to examine the portion of the tegumentary skeleton belonging to the extremities or that portion of the external skeleton of the Crustacea which may be regarded as an appendage to the more essential covering of the head, thorax, and abdomen.

The Crustacea present this invariable character, that the whole of the appendages belong exclusively to the inferior arc of their tegumentary rings, a point in which they resemble the Arachnidans, and differ like these from Insects, in which one or two of the thoracic rings generally present a pair of extremities supported by the superior arcs, as in the Annelidans, in which the dorsal segment of each of the rings almost always carries a pair of extremities fashioned in the same manner as those belonging to the ventral arcs.* We have already said that a pair of appendages ought to be found attached to each ring; but it very frequently happens that many of the pairs are completely checked in their development, or that the forms they assume, in harmony with the uses they serve, render them liable to be mistaken. It is very different in the embryo; here, in fact, as among the simplest forms of the series, the whole of the extremities are at first similar; and it is only in consequence of ulterior developments that each pair finally assumes diversities of form and character in relation with the various functions to which they are especially destined.

In its most perfect state of development, the extremity in the Crustacean consists of three principal parts: the *stem* (*a*), which is the most essential and most constant part, formed of a variable number of articulations; the *palp* (*b*), an appendage which is detached from one of the three first articulations of the stem, but almost always from the first; and the *whip (fouet)* (*c*), which is sent off above and to the outer side of the palp. It but rarely happens, however, that these three organs exist simultaneously; occasionally not more than one of them can be demonstrated; and sometimes the whole three are altogether wanting.

Fig. 386.

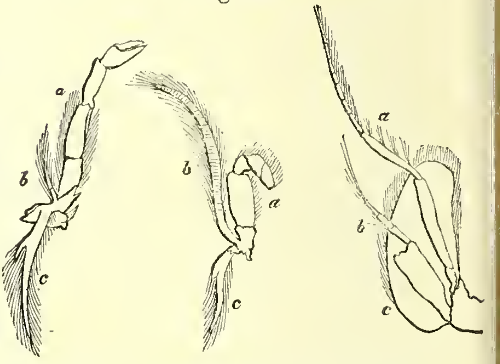


Fig. 387.

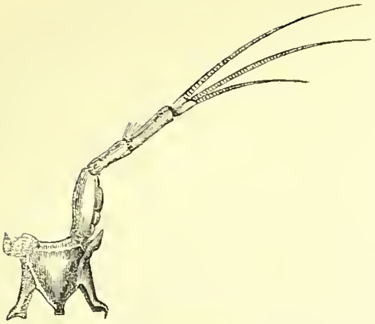
First cephalic ring of the Squilla separated from the rest of the head, and bearing one of the ocular peduncles.

The first ring presents no appendages except in the very highest Crustaceans, and even then they are simple in their composition, and never exhibit more than the stem, which arises from a more remote check to their development dating from about the commencement of their embryonic evolution; these are the *ocular peduncles.*

The second and third pairs of extremities constitute the *antennæ.* These are wanting in a certain number of the inferior species, and even in those among which they occur, they vary considerably in their structure: they may for instance present one only, or two, or the whole of the three elements of which we have spoken. But as the three first pairs of ap-

* Vide Annelida, p. 167.

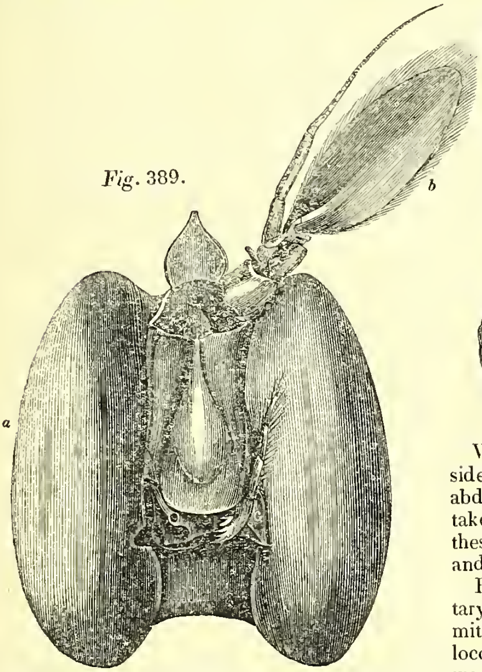
Fig. 388.



a, second thoracic ring of the Squilla; *b*, one of the small antennæ.

pendages belong espcecially to the function of sensation, and as we shall have to revert to these at a later period, and give an ample description of their structure, we shall not enter upon this subject farther at present.

Fig. 389.



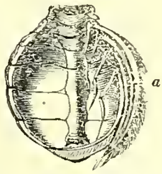
Third and fourth cephalic rings of the Squilla: *a*, carapace; *b*, one of the posterior antennæ; *c*, one of the mandibles.

The eleven pairs of appendages which succeed are variously apportioned between the functions of digestion and locomotion, to which last the five hindmost pairs are entirely dedicated in the Decapods. In other Crustacea, again, the first pair only is set apart in an especial manner for the office of mastication, all the others then serving for locomotion, and this pair is in consequence very generally described under the name of *mandibles;* very commonly one and even two other pairs are added to this first pair, and these are designated *jaws* or *maxillæ*. In the majority of instances, moreover, the three succeeding pairs assist the three preceding; and as they are frequently more especially apportioned to locomotion, the two last in particular, whilst in some cases they serve for the two functions at one and the same time, they have been designated by anatomists and naturalists the *maxillary limbs* (*pieds-machoirs*): these we shall describe when we come to speak of the apparatus of digestion.

As to the five pairs which we have already mentioned as essentially *ambulatory* (see *fig.* 382), they present in the Brachyura no more than a simple stem, composed of six articulations; whilst in the Astacus and allied genera, we find a *flabelliform* appendage or whip, dedicated especially to the purposes of respiration, and in the Peneæ the three sorts of appendages existing simultaneously. By-and-by, when speaking of respiration, we shall see how it happens that in a great number of these animals the *whip* of the thoracic extremities assumes a vesicular structure, and becomes the organ of this important function.

The same peculiarity is observed in the appendages of the abdominal extremities of a great number of species; but among the members of the most elevated tribes, these appendages are but very slightly developed, and appear to have no other use than to attach the eggs along the inferior surface of the abdomen.

Fig. 390.



Abdomen of the female Maja Squinado.
a, the abdominal appendages.

We shall not at present enter upon the consideration of the forms of the thoracic and abdominal extremities, having it in view to take up the subject when we come to examine these appendages as the organs of prehension, and as fulfilling important offices in locomotion.

Before quitting the study of the tegumentary skeleton, to go on to that of the extremities considered especially as the organs of locomotion, we think it necessary to say a few words upon the *moult* or process by which the tegumentary covering of the whole of the Crustacean is cast off and renewed.

The necessity for this operation is a consequence of the very nature of the envelope: like every other epidermic covering, the product of secretion, the shell of the Crustacea is closed in on every side, and can only increase in thickness, so that all growth would be prevented in the body of these animals were they denied the power of freeing themselves from time to time of their prison. Accordingly they have this power; and as might have been expected the shell is cast by so much the more frequently as the animal is younger, inasmuch as the growth is then most rapid; as many as eight changes of the tegumentary envelope have been observed to take place in the course of seventeen days in the young Daphnia; whilst in adult Crustacea the change is not in general effected oftener than once a year.

Réaumur watched the phenomenon through its whole course, and has noted it with all its details as it occurs in the *Astacus fluviatilis*.* It takes place in this species towards the end of summer or beginning of autumn. A few days of fasting and sickness precede it, during which the carapace becomes loosened from the corium to which it adhered, and which immediately begins to secrete a new one, soft and membranous at first, but soon becoming harder and harder, and finally completely calcareous. In this way the animal before long finds itself free from all connexion with its old envelope, and it has only to make its escape. This last operation is announced by symptoms of inquietude. The creature rubs its legs one against another, and then throwing itself upon its back begins to shake itself, puffs itself out, so as to tear the membrane which connects the carapace with the abdomen, and to raise the carapace itself. After sundry intervals of rest and agitation of longer or shorter duration, the carapace is raised completely; the animal extricates its head, its eyes, and its antennæ. The operation of freeing its extremities appears to be the most difficult, and would even be impossible did not the solid covering of these parts split longitudinally; but in spite of every assistance, it not unfrequently happens that the animal leaves one or two of its limbs impacted within the old sheath, and occasionally even perishes through inability to escape completely from its shell. The abdomen is the last division of the body which clears itself of the old envelope. All the parts of the tegumentary skeleton which had only been separated from one another, without however having undergone any softening, or fracture, or separation, fall one upon another in resuming their old positions, so as to represent the complete external form of the creature with the whole of its solid internal as well as external parts; even the eyes, the antennæ, and the thoracic cells formed by the sternal and epimeral apodemata, may be distinguished. The operation now described does not in general occupy more than half an hour in the performance; and only two or three days, or even no more than four-and-twenty hours are required to convert the soft and membranous envelope with which the corium or naked body of the animal is surrounded, into a firm calcareous covering similar to the one which has just been got rid of. The new envelope presents the same appendages as the former one, even the same hairs; but these, instead of being contained within the old ones, as Réaumur imagined, exist ready formed in the new envelope, but turned in towards the interior, like the fingers of a glove turned in upon themselves.

* Mémoires de l'Academie des Sciences, 1718.

There are some species, such as the Crabs and the Brachyura generally, in which the carapace presents a considerable expansion on either side, forming two large compartments in which the greater mass of the thoracic viscera is contained. Under these circumstances it would be impossible for the animal to escape from its dorsal covering by the relatively inconsiderable opening which this part presents on its inferior aspect. This renders it necessary that the carapace, instead of being cast off by simply rising in a single piece, should give way and separate in some direction or another, and this it does by splitting along the curved lines, extending on either side from the mouth to the origin of the abdomen, in the course of which the epimeral pieces cohere with the dorsal one.*

The time occupied in the business of throwing off the shell varies considerably in different species; it is also dependent on atmospheric influences. It is the same also, in regard to the number of days necessary to give to the new epidermic layer the consistency of the old tegumentary covering. A general remark, however, and one which is applicable to the whole of the species that have been duly observed, especially those that are found along the shores of France, is this,—that the period which precedes as well as that which follows the change of the shell is one of restlessness and evident illness. The muscles of these creatures are then flaccid, the flesh is soft and watery, and as food they are rejected as tasteless and held unwholesome. This would not appear to be the case with the Land-crab, however, according to the statements of several travellers, who inform us that the flesh of this species is never in greater perfection than during the season of the moult.

A phenomenon, which has some analogy with the renovation of the tegumentary skeleton, but which is much more curious, is the reproduction of the legs of these animals. Most Crustacea cast off their claws very easily and without apparent pain; the separation always takes place in a determinate point near the basis of the member (in the second articulation), and is soon followed by the formation of a cicatrice, from the surface of which sprouts out a small cylindrical appendage; this shortly after presents distinct articulations, and resembles in miniature the organ it is destined to form, but its growth is slow, and it does not for some time attain its full size. If one of the limbs be severed in any other part, the wound continues to bleed, and no renovating process begins unless the animal, by a violent muscular contraction, succeeds in breaking off the stump in the articulation above mentioned.

The kind of solid sheath formed by the tegumentary skeleton of the Crustacea, and which includes in its interior the whole of the viscera and other soft parts of these animals required to be so constructed as not to oppose locomotion; consequently there exist,

* Collinson, Phil. Trans. 1746 and 1751; Hist. Nat. des Crustacés, t. i. p. 56.

either between the different rings of the body or the various constituent elements of the limbs, articulations destined to admit of motion to a greater or less extent, between these different pieces. The structure of these articulations is of the most simple kind; the moveable piece rests upon that which precedes it by two hinge-like joints situated at the two extremities of a line perpendicular to the plane in which the motion takes place. In the internal portion of the edge of the moveable piece comprised between the joints, there exists a notch of greater or less depth, destined to admit of flexion, whilst on the opposite or external side, the same edge generally glides under that of the preceding piece. This kind of articulation, whilst it is the most favourable to precision of movement and to strength, has the disadvantage of admitting motion in one plane only; therefore the whole of the rings of the body, the axis of motion being entirely parallel, cannot move save in a vertical plane; but nature has introduced a kind of corrective of this disadvantage in the structure of the limbs, by changing the directions of the articular axes, whence ensues the possibility of general motions being performed in every direction. Between the two fixed points two opposed empty spaces are observed, left by the rings severally, and destined to admit of the occurrence of motions of flexion and extension. The tegumentary membrane which fills it never becomes encrusted or calcareous, but always continues soft and flexible.

The tegumentary skeleton, of which we have thus taken a summary view, supplies the apparatus of locomotion with fixed points of action as well as with the levers necessary to motion. The immediate or *active* organs of this apparatus are the muscles, the colour of which is white, and the structure of which presents no peculiarity worthy of notice. They are attached to the pieces which they are required to move either immediately, or by the intermedium of horny or calcareous tendons, which are implanted upon the edge of the segment to which they belong. To the fixed point they are most commonly attached immediately. Their structure is simple, and each segment, in fact, as has already been said, being contrived to move in one fixed and determinate plane, the muscles which communicate motion to it, can constitute no more than two systems antagonists to each other, the one acting in the sense of *flexion*, by which the segment moved is approximated to that which precedes it, the other in the sense of *extension*, by which the segment is brought into the position most remote from the centre of motion. The muscles that produce these opposite effects, as might have been concluded, are found implanted into the opposite arms of the lever upon which their energy is expended.

The motions in flexion tend universally to bring the extremities and the different rings towards the ventral aspect of the body; it is consequently upon this aspect that the flexor muscles are inserted, and these are in general the more powerful. On the contrary, and in accordance with the nature of the motion produced, it is upon the superior or dorsal aspect of the segments that the extensor muscles are attached. In the trunk the two orders of muscles generally form two distinct layers, the one superficial, the other deep; the former thin and sometimes absent, the second, on the contrary, very powerful wherever powerful motions are required. The muscles generally extend from the arc above to the one immediately below, passing for the most part from the anterior edge of the upper to the anterior edge of the lower segment. The extent and the direction of the flexion of which any segment is susceptible, depend on the size of the interannular spaces above or below the ginglymoid points; and as these spaces are in general of considerable magnitude on the ventral aspect, whilst the superior arcs are in contact and can only ride one over another in a greater or less degree, it is only downwards that the body can be bent upon itself; while upwards, or in the sense of extension, it can hardly in general be brought into the horizontal line.

Thus far what has been said applies more especially to the rings of the body, but the extremities present nothing that is essentially different either as regards the mode in which the tubular segments are articulated to one another, or as regards the mode in which the muscles are inserted. Each of these indeed having but one kind of motion, and even that very limited in its extent, nature has aided the deficiency, as has been stated, by increasing the number of articulations, by which extent of motion is conferred, and in varying the direction of the articular axes, an arrangement by which the animal obtains the ability of moving in every direction, but at the expense both of power, rapidity, and precision in its motions. Each segment of a limb encloses the muscles destined to move that segment which succeeds it, unless it be too short and weak for this end, in which case the muscles themselves have their origin at some point nearer to the median plane of the body. As a general law the muscles are observed to be more powerful in proportion as they are nearer to the centre, which is to be explained by the fact that each motion they then communicate is transmitted to a larger portion of a limb, to a lever longer in that sense in which it is disadvantageous to the power. Occasionally, however, the two last segments of a member are converted into a sort of hand, and in this case the penultimate segment sometimes includes a muscular mass which may surpass in power the same system in the whole of the limb besides. Those muscles that put an extremity generally into motion, are attached to the sides of the thoracic cavity, and the apodemata supply them with surfaces of insertion of great extent and very favourably situated as regards their action. They occupy the double rank of cells formed by these laminæ; but they vary too much in their mode of arrangement to admit of our saying any thing general upon this head. The motions of translation, or from place to place, the only kind upon which it seems necessary to say anything here, are effected in two modes, either by the alternate flexion and extension of the trunk, or by the play of the limbs.

In those Crustacea which are formed essentially for swimming, the posterior part of the body is the principal agent in enabling the animal to change its place; but here the motions, instead of being lateral, are vertical; and instead of causing the creature to advance they cause it to recede: it is by bending the abdomen suddenly downwards, and bringing it immediately under the sternum, that it strikes the water, and consequently by darting backwards that the animal makes its way through that liquid. From what has now been said it may be imagined that the Crustacea whose conformation is the best adapted for swimming, have the abdomen relatively largely developed, and this is, in fact, what we always observe; the Amphipoda and Decapoda macroura are examples; whilst, in the walking Crustacea, such as the Crabs, the Caprella, the Oniscus, &c. this portion of the body attains but very insignificant dimensions.

In the swimming Crustacea the appendages of the penultimate segment of the abdomen also become important organs of locomotion, inasmuch as they for the most part terminate in two broad horizontal plates, which, with the last segment, also become lamelliform, constitute an extensive caudal fin arranged in the manner of a fan.

We have already said that the thoracic extremities alone constitute true ambulatory limbs. When destined for swimming only, their segments are lamelliform, and the palp, as well as the stem, contributes to form the kind of oar which each of them then constitutes. The Copepoda supply us with instances of thoracic extremities particularly destined for swimming, and a corresponding structure is observed in certain Podophthalmia, such as the Mysis. (See *fig.* 386.)

To conclude, this stemmatous portion of the thoracic extremities, whilst it still preserves the general form which we have assigned it, is modified in some cases to serve for walking as well as swimming, or to aid the animal as an instrument for burrowing with facility, and making a cavity for shelter among the sand. Thus in the Decapods that burrow, the last segment of the tarsus assumes a lanceolated form, and in the swimming Brachyura, the same segment, especially of the last pair of extremities, appears entirely lamellar.

We have only further to add that in a great number of species one or several pairs of the thoracic extremities are modified so as to become instruments of prehension; sometimes it is the last segment of the limb which, acquiring more than usual mobility, bends in such a manner as to form a hook with the preceding segment; sometimes it is this penultimate segment which extends below or by the side of the last, so as to form a kind of immoveable finger with which it is placed in opposition. In the first instance these instruments are denominated *subcheliform claws,* in the second *chelæ* simply, or *cheliform claws.* We shall revert to these organs when we come to treat of the apparatus of digestion.

§ 2. *Apparatus of Sensation.*

A. *Nervous System.*—When endeavouring to form as accurate and complete an idea as possible of the tegumentary skeleton of the Crustacea, we began by studying it in its successive states of development in the embryo, and then compared the various stages of transition in which it met our observation, with the permanent conditions in which it finally remains in the organic series, classed in conformity with the structural affinities of the different genera. In the study of the nervous system, upon which we are now about to enter, the same mode of proceeding will lead us to analogous results.

The deep situation of the nervous system, and the transparency of the filaments and various masses which compose it, are each obstacles to its observation until it has arrived at a somewhat advanced stage of development. It was, in fact, only after the sternal canal had begun to appear under the form of an enlargement, edged by a double series of tubercles, which prove to be the rudiments of the motor muscles of the extremities, that Rathke* was able to catch a sight of the earliest traces of the nervous system in the Astacus fluviatilis, and even this was no more than the portions belonging to the head and thorax. All that can be seen then amounts to very little; in the part behind the mouth, eleven pairs of whitish spots are arranged in two longitudinal series perfectly distinct from one another, and situated on either side of the mesial plane. It is otherwise easy to perceive that a pair of these spots corresponds to each ring, setting out from, but including those of the mandibles. Neither the œsophageal cords nor the cephalic ganglions are then distinct.

At a later period these rudiments of the nervous system undergo remarkable modifications. The six first ganglions of each series approach those that are symmetrical with them severally, so as to become united along the median line, and, at length, to form a simple chain of ganglions corresponding to the six rings, whose appendages are the mandibles and the five pairs of maxillary extremities. The ganglions, on the contrary, which correspond to the five posterior thoracic rings, continue to form a double series. During this time the sternal canal is evolved so as to surround the nervous system with a firm and solid sheath. At a period of the incubation still farther advanced, that is to say, during the time which elapses from the birth of the young Crustacean to that at which it attains its full growth, new and important changes take place. First, the four most anterior œsophageal tubercles, in other words, those which correspond to the mandibles, to the jaws, and to the first pair of maxillary limbs, become united, by approaching one another along the mesial line, so

* Untersuchungen über die Bildung des Flusskrebses.

as finally to constitute a single continuous mass only. The same thing happens in regard to the fifth and sixth, which soon form no more than a single ganglion. As to the other pairs they always remain completely distinct, and some way parted from one another.

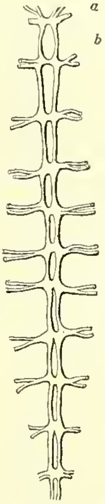
Thus the study of the gradual evolution of the nervous system in the Astacus fluviatilis, although by no means belonging to the type in which this system is most completely developed, presents us with three distinct and successive facts, which we shall find reproduced in the most perfect manner in the natural series of genera, and which will put us into a position to give a satisfactory explanation of those very striking variations in the organization which we shall encounter.

These are, in the first place, the isolated formation of the nervous centres, independently one of another. We now acknowledge this independence of the several organs at the moment of their appearance, and their ulterior conjunction is one of the most interesting and important facts with which modern science has been enriched; it constitutes the law of *centripetal development*, as it has been established by M. Serres.

In the second place a tendency to conjunction by a motion transversely.

Lastly, a second motion in the line of the axis of the body, the effect of which is the concentration definitively of a greater or smaller number of nervous centres primarily independent of one another.

Fig. 391.



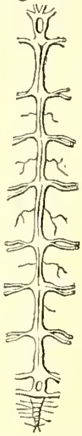
Nervous system of the Talitrus.
a, cephalic ganglia; *b*, medullary cords uniting the first and second pair of ganglia.

The Talitrus exhibits in the most striking manner the first of the three dispositions which we have mentioned from the moment at which the nervous system appears. In this genus, in fact, we perceive on either side of the median line a ganglionic chain, formed by the conjunction of the nervous centres, extremely simple in their structure, and flattened and somewhat lozenge-shaped in their outline.* There are thirteen pairs thus constituted, corresponding to the thirteen segments which enter into the composition of the whole body. The two nuclei of each pair communicate together, in the same manner as each pair is connected with that which succeeds, and with that which precedes it, by means of medullary cords in the first instance, and longitudinal cords in the second. In all essential particulars each pair is a counterpart of any and every other pair, without even excepting the cephalic ganglion, and it is with difficulty that the thoracic pairs are seen to be in a slight degree larger than the others. At a somewhat greater distance forward from the œsophagus, too, than usual, we observe the cephalic ganglion, which sends branches to the antennæ and eyes, and the nervous cords by means of which it communicates with the ganglions of the first thoracic rings. These cords, having the œsophagus interposed between them, are held a little farther apart than the other branches, which establish communications between the different succeeding pairs of ganglions in the longitudinal direction.

Already in the *Oniscus asellus** and in the *Cyamus ceti*† we find the ganglionic cord, double in its middle portions, simplified at its opposite extremities in such wise that the ganglions of the first and of the last pairs are single. This commencement of approximation coincides in other respects with an incipient approximation in the longitudinal direction, for, to the fourteen segments of which the whole body consists, we find no more than ten pairs of ganglions apportioned.

This tendency to centralization is still more conspicuous in the Phyllosoma.‡ Here we discover the two cephalic nuclei united by their internal angle, without, however, their state of doubleness being thereby obscured. It is the same with the first pair of thoracic ganglions, from which they are separated by the whole length of the great oval lamina which supports the cephalic appendages and is traversed lengthwise by the nervous filaments which embrace the œsophagus. The ganglions of the second pair, although rudimentary, are still united immediately, as are those of the third pair also. Those of the six succeeding pairs, on the contrary, only communicate by means of a transverse but thick and short commissure, so that it gives to the connexion established between the nuclei of the several pairs, the appearance of a more immediate conjunction than actually exists. To conclude, the abdominal ganglions are perfectly distinct, and those of the several pairs are only connected by means of extremely slender filaments.

Fig. 392.



Nervous system of the Cymothoa.

In the Cymothoa the union of the medullary nuclei in the transverse direction is complete, and all we perceive is a single series extended along the median line through the whole length of the body. This is similar to the nervous system of the Talitrus conjoined longitudinally; with this difference, that the longitudinal filaments uniting the ganglion have continued distinct, as if to testify, by their doubleness, to the mode of formation of the single ganglionic cord.

* Vide Recherches Anatomiques sur le Systême Nerveux des Crustacés, par M M. Audouin et Milne Edwards, Annales des Sciences Naturelles, tom. 14.

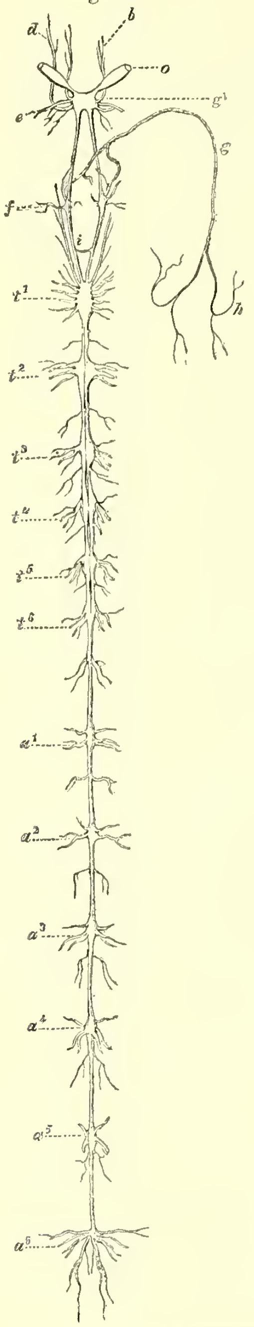
* Cuvier, Leçons d'Anatomie comparée, t. ii. p. 314.

† Treviranus, Vermischte Schriften anatomischer und physiologischer inhalts, Band 2. Heft I.

‡ Audouin et Edwards, loc. cit.

But it is more especially in the types which still ask our attention, that we perceive the system of centralization pushed yet farther by the actual conjunction of the nuclei, which we have hitherto only seen approximated to one another, in consequence of their gliding or encroaching, as it were, upon the median line.

Fig. 393.



Nervous system of the Astacus Marinus, or Sphinx Ligustri.

The Lobster (*Astacus marinus*) (*fig.* 393) presents us with another step in the system of centralisation. Here, in fact, the longitudinal cords of communication are entirely consolidated along the median line through the whole of the abdomen, although they are still to be found double in the thorax. Moreover, the first thoracic ganglion (t^4), and the last of the abdominal series of ganglions (a^6), are conspicuously formed by the reunion of several distinct nervous centres, in the way we have already indicated as happening, although in a minor degree and less perfectly, in the Amphipoda and the Isopoda. Before we pass, however, to the consideration of more complicated systems, we shall pause a moment to describe somewhat at length the one which we have but just mentioned, the more as it is among the number of those which have been most attentively studied.

The cephalic ganglion (g^1, *fig.* 393), situated above the base of the internal antennæ, is of considerable size, and appears to be simple; it gives origin to five pairs of nerves and to two cords, which connect it with the rest of the ganglionic nervous system. The first of these pairs (*o*) arises from its anterior edge: this is the optic pair, which, after having penetrated the peduncles of the eyes, increase in size, and traverse a membranous diaphragm, which may be likened to the sclerotic coat.

The second pair of nerves correspond to the ocular motors; they run parallel to the preceding pair, and are distributed to the muscles of the eyeball.

The third pair proceed to the internal antennæ (*b*); but before they enter these appendages they send off a branch to the muscles which move them. A like ramification is sent off from the principal trunk to each of the rings of which these antennæ are composed, and the nerve ends by becoming bifurcated, in order to penetrate the two filaments in which the antennæ terminate.

The fourth pair of nerves (*e*) are distributed to the tegumentary membranes of the anterior extremity of the animal. Behind the fourth a fifth pair is seen (*d*), which proceeds anteriorly to the fourth pair almost immediately after its origin, sends one branch to the cake-like organ of doubtful function which covers the ear, a second branch to the organ of hearing itself, and finally terminates in a trunk of considerable size, which traverses the external or second antenna through its entire length.

A sixth pair is destined to establish connexions between the cephalic ganglion and the first of the thoracic ganglions, after having surrounded the œsophagus; but instead of appearing as simple nervous cords through their whole length, as in types which we have hitherto studied, each of them presents an enlargement in its middle, which is neither more nor less than a ganglion, from which there is sent off, first, a nerve that proceeds to the mandibles (*f*); next, a gastric nerve (*g*), of large size, which gives many filaments to the coats of the stomach, and finally anastomoses with the corresponding cord of the opposite side; after this the two form a single nerve, which by-and-by presents an enlargement having the appearance of a small median ganglion, and then remounts upon the dorsal aspect of the stomach to ramify there, and ultimately to lose itself upon the intestine (*h*). Behind the stomach a transverse cord (*i*) is seen, which connects the two nervous filaments, and appears to be the cord of communication between the ganglion of which mention has just been made, pushed backwards, in the same way as the ganglions themselves have been kept apart, to wit, by the resistance of the œsophagus, interposed at the time when that process is going on by which the pairs generally are approximated in the course of the median line.

The first of the thoracic nervous masses (t^1) is oval-shaped, and gives origin to ten pairs of nerves, five of which issue from the anterior aspect. The first run to the mandibles and to their muscles; the second to the auditory apparatus; the third to the first jaw, the fourth to the second jaw; the fifth to the cells of the flancs, to the muscles and neighbouring integuments; the sixth and seventh arise from the inferior aspect of the nervous mass to proceed to the maxillary feet; the nerves of the eighth pair are extremely slender, and are distributed to the muscles of the thorax; the two succeeding pairs belong to the third pair of maxillary extremities; lastly, two cylindrical cords arise from the posterior extremity of this nervous centre, and connect it with the second thoracic ganglion, giving origin themselves in their passage to a pair of extremely minute filaments, which run to be distributed to the muscles of the thorax.

This first thoracic nervous mass represents, therefore, the five pairs of ganglions which follow the mandibular ring, and must be viewed as resulting from the concentration of the five pairs of medullary nuclei belonging to the five rings which bear the accessory masticatory organs. In the adult Lobster the different elementary constituents are not traceable, and the whole mass appears to be composed of no more than two ganglions closely connected in the median plane; but in a species very nearly allied, namely, the River-crab (*Astacus fluviatilis*), very obvious traces of the existence of several medullary nuclei can always be demonstrated in its interior. The five pairs of ganglions that follow (t^2—t^6), and that belong to the five last thoracic rings, have, on the contrary, continued distinct; although simple, these nervous centres still exhibit manifest indications of their composition severally by two nuclei; from either half we have a cord of communication sent off, similar to those which we have already pointed out as existing between the first and second thoracic ganglions; the whole of these inter-ganglionic cords are in contact along the median line, except the penultimate or antepenultimate pairs, which are separated from one another by the sternal artery, in the same manner as those of the head are kept asunder for the passage of the œsophagus.

Each of these five thoracic ganglions sends two pairs of nerves to the ambulatory extremities which correspond to them severally. Of these two nerves, the posterior and larger sends branches to the basilar articulations of the extremities; the anterior, again, distributes twigs to the muscles of the flancs; the two soon anastomose, and form a single trunk before penetrating into the extremity itself, which then traverses the whole limb, sending a branch to the muscles of each articulation.

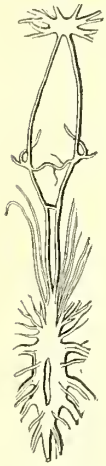
The abdominal ganglions (a^1—a^6) are smaller than the preceding ones, and are connected by simple longitudinal cords. They also supply two pairs of nerves, the one destined to the muscles of the abdomen, the other to the appendages of the ring with which it corresponds. As in the thorax, nervous fibres, distributed to the median and superior part of the abdomen, are observed proceeding from the cords which establish a communication between one ganglion and another.

The last ganglion (a^6), which appears to be made up of the medullary nuclei belonging to the sixth and seventh segments of the abdomen, gives origin to four pairs of nerves, which run to the penultimate articulation of the abdomen, and to the last, which is of a flattened form, and along with the appendages of the former constitutes the kind of horizontal oar which terminates this part of the body.

Such is the nervous system in the Lobster. If we study it in the Palemon, we shall find precisely the same elements, but with a still higher degree of centralization, for the ganglia of the three lowest thoracic rings are consolidated into one, and situated much forwards, so that the nerves to which they give origin have to pursue a very oblique course, in order to reach the parts to which they are distributed respectively. The ganglion of the second pair is isolated; that of the first pair of ambulatory extremities blends and is confounded with that of the third pair of maxillary limbs. The five anterior pairs of œsophageal ganglions, in fine, are united into a single nervous centre. There are consequently, properly speaking, no more than four medullary masses in the whole length of the cephalo-thoracic portion of the Palemon; and even these are very close to one another, and all but united, their longitudinal commissures being thick and simple, and bearing as close a resemblance to constrictions in a single nucleus as to bands of communication between distinct nuclei. The fourth of these four ganglions presents a longitudinal cleft through its centre, a structure which is easily explained by the presence at this point of the sternal artery, which existed there before the ganglia became conjoined in the course of the median line, and necessarily opposed a merely mechanical obstacle to their entire union.

In the Palinurus the whole of the thoracic ganglia, strictly speaking, are united into a single mass of a greatly elongated form, and presenting a little way back, like the fourth ganglion of the Palemon, a cleft for the transmission of the sternal artery.

Fig. 394.



Cephalo-thoracic portion of the nervous system of the Palinurus Vulgaris.

The transition from the Decapoda Macroura to the Brachyura takes place by the Homola, and certain Anomoura,* in which the constantly increasing concentration of the thoracic nervous centres coincides with the almost rudimentary state of the abdominal ganglionic system, which is here reduced to a kind of median trunk without enlargements.

This, too, is the disposition presented by the nervous system in the Carcinus mœnas among the Brachyura, with this difference only, that the medullary nuclei are rather closer to one another, and more intimately connected.† The thoracic ganglion has the form of a ring, the circumference of which gives origin to the nerves of the thoracic appendages. The single abdominal cord is in its rudimentary state, in obvious relation with the abdomen itself, and therefore reduced to very insignificant dimensions.

It is in the Maja,‡ in fine (*fig.* 395), that the nervous system is found in its highest degree of centralization; for the elements of which the two masses there encountered are composed, are so intimately conjoined, that no trace can be found of their ever having existed independently, although among neighbouring genera several of them may still be discovered isolatedly. The cephalic ganglion (*a*) is a sufficiently faithful counterpart of that of the Lobster. The nervous cords (*g*) which connect this first portion of the system with the thoracic portion also present the same arrangement as in the Lobster; there are similar mandibular nerves, a like gastric pair, the same transverse band (*g'*) behind the œsophagus, &c. But the thoracic ganglion (*l*), instead of the ring which it presents in the Carcinus mœnas, here appears as a solid circular and flattened nucleus giving origin to the whole of the nerves of the thorax and abdomen, which radiate from it to the number of nine pairs, and one azygous nerve situated in the median plane. There is nothing very remarkable in the distribution of these nerves, unless it be that several pairs, and among the number the first and second, are distributed simultaneously to several rings, which proclaims that in the species which engages us the work of concentration has extended from the ganglions to the nervous cords.

Fig. 395.

Nervous system of the Maja Squinado.

a, cephalic ganglion; *b*, optic nerves; *c*, oculo-motor nerves; *d*, nerves of the antennulæ; *e*, fourth pair of nerves belonging to the integuments; *f*, nerves of the exterior antennæ; *g*, medullary cords uniting the cephalic and thoracic ganglions; *g'*, transverse cord; *h*, mandibular ganglion; *h'*, small nerve belonging to the muscles of the mandible; *i*, stomato-gastric nerve; *k*, lateral branches of the stomato-gastric nerves; *l*, thoracic ganglion; *m*, nerves of the maxillæ; *n*, nerves of the first pair of legs; *o*, abdominal nerve; *p*, cells of the flancs; *q*, arch of the flancs.

Any farther detail in addition to what has now been said would contribute little to our essential knowledge of the nervous system. We have traced it from its commencement in

* Vide Rech. sur l'organiz. et la classific. des Crustacés Decapodes par M. Milne Edwards; Annales des Sciences Naturelles, t. xv.

† Cuvier, Leçons d'Anatomie Comparée, t. ii. p. 314.

‡ Audouin et Edwards, loc. cit.

a series of independent centres, and we have seen these becoming successively conjoined in a greater and greater degree, as if in obedience to a law of attraction, whose tendency was to collect these various nuclei from every part of the body towards a common centre. This disposition to centralization has, in its turn, given a satisfactory explanation of the most remarkable differences observed in the disposition of the ganglions and of the nervous cords among the different types of the class, however dissimilar these may be one from another. We may, therefore, here conclude, as has been done already in my work especially devoted to this subject, that *the nervous system of the Crustacea consists uniformly of medullary nuclei (ganglions), the normal number of which is the same as that of the members or rings of the body, and that all the modifications encountered, whether at different periods of the incubation, or in different species of the series, depend especially on the approximation, more or less complete, of these nuclei, (an approximation which takes place from the sides towards the median line as well as in the longitudinal direction,) and to an arrest of development occurring in a variable number of the nuclei.*

In a paper upon the nervous system of the Lobster recently published,* Mr. Newport mentions an interesting fact hitherto overlooked by anatomists. He found that the double ganglionic chain of this Crustacean is composed of two orders of fibres, forming distinct and superposed fasciculi or columns, which the author designates *columns of sensation* and *of motion*, following the analogy which he believed he had traced between these fasciculi and the anterior and posterior columns of the spinal cord of the higher animals. The fasciculi here indicated are but indistinct in the interganglionic cords, but become extremely apparent in the ganglions themselves, for these enlargements belong exclusively to the inferior or *sensitive* fasciculi, and the superior or *motor* fasciculi pass over their dorsal surface without penetrating their substance at all.

Before going on to the study of those organs the object of which is the application, if we may be allowed the expression, of the nervous system to the perception of the existence of outward objects, and of those in which the *reaction* designated *volition* is immediately effected, that is to say, the organs of the senses and the muscles, it may be as well to say a word upon the general functions of the nervous system itself in its different parts. The experiments made by M. Audouin and me, with a view to solve the principal problems which may be proposed on this subject, have confirmed the inductions to which we had been led by views arrived at *a priori* wholly from anatomical researches, of which the preceding may be regarded as the summary. Thus:—

1stly, The nervous is the system which entirely presides over the sensations and motions.

2dly, The nervous cords are merely the organs of transmission of the sensations and of volition, and it is in the ganglions that the power of perceiving the former and of producing the latter resides. Every organ separated from its nervous centre speedily loses all motion and sensation.

3dly, The whole of the ganglions have analogous properties: the faculty of determining motions and of receiving sensations exists in each of these organs; and the action of each is by so much the more independent as its development is more isolated. When the ganglionic chain is nearly uniform through its whole length, it may be divided without the action of the apparatus being destroyed in either portion thus isolated,—always understood, that both are of considerable size; because when a very small portion only is isolated from the rest of the system, this appears too weak, as it were, to continue its functions, so that sensibility and contractility are alike speedily lost. But when one portion of the ganglionic chain has attained a development very superior to that of the rest, its action becomes essential to the integrity of the functions of the whole.

It must not be imagined, however, from this that sensibility and the faculty of exciting muscular contractions are ever completely concentrated in the cephalic ganglions, and it seems to us calculated to convey a very inaccurate idea of the nature and functions of these ganglions to speak of them under the name of *brain*, as the generality of writers have been led to do, seduced by certain inconclusive analogies in point of form and position.

It is nevertheless to be remarked that in these animals an obscure tendency to the centralization of the nervous functions is observable in the anterior portion of the ganglionic chain; because if in the Lobster, for instance, it be divided into two portions, as nearly equal as possible, by severing the cords of communication between the ganglions belonging to the first and second thoracic rings, sensibility, and especially mobility, are much more quickly lost in the posterior than in the anterior half; and this disproportion is by so much the more manifest as the division is performed more posteriorly; still there is a great interval between this first indication and the concentration of the faculties of perception and of will in a single organ—the brain, of which every other portion of the nervous system then becomes a mere dependency.

B. *Organs of the senses.*—Do the five senses exist, and to what degree of development have they attained in the Crustacea? Such is the question we have now to consider, and which we shall sometimes find ourselves in a condition to answer from the simple inspection of the various organs of special application.

Thus we discover almost at once that the sense of general *touch* is obtuse, and can convey to the animal no other but confused

* On the Nervous System of the Sphinx ligustri, &c. by G. Newport, Philos. Transact. 1834, pt. ii. p. 406.

notions of the existence and of the resistance of the bodies with which it finds itself in immediate relationship by its external surface. To be satisfied of this, it is enough to consider for a moment the hard and unyielding nature of the general tegumentary envelope over every point of the body except the articulations,—parts which on other grounds are obviously inadequate to exercise any sense whatever.

Nevertheless, in front of the head there are certain special organs which all the observations I have had an opportunity of making upon the organization of these animals lead me to regard as parts more particularly destined to be the seat of the sense of *touch*. These organs are the antennæ,—those slender filaments, possessed of a great degree of flexibility, of motility, and of sensibility. M. de Blainville was led to regard these organs as the seat of the sense of smell; but direct and conclusive experiment has satisfied us that the destruction of the antennæ has no influence whatever on the exercise of the sense of smell: and we are on the same grounds induced to believe them destined to the exercise of the sense of touch of considerable delicacy, unless we would imagine them as the instruments of some quite peculiar sense the existence of which would be purely hypothetical.

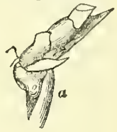
The number and disposition of these organs varies extremely. Some of the Crustaceans at the very bottom of the series are wholly without antennæ, or are furnished with them in a merely rudimentary state. Some species have no more than a single pair; the normal number, however, is two pairs. In speaking of the tegumentary skeleton, we have said to which of the rings these appendages belong; we shall only say farther here, that they may be inserted on the superior or on the inferior surface of the head according to the respective development of the different pieces of which this segment is composed. They do not differ less widely in their form and composition, and under this double point of view present modifications analogous to those which we have specified as occurring in the extremities.

The Crustaceans, like almost all other animals, make a selection of matters in especial relationship with the state of their organs of nutrition; they must therefore be endowed with the sense of *taste*. With reference to the seat of this faculty, which perchance is the modification of sensibility the least remote from the sense of touch, it appears to reside in the Crustacea, as it does obviously in the majority of animals, in that portion of the tegumentary membrane which lines the interior of the mouth and œsophagus; but the disposition of the parts there presents no peculiarity worthy of especial notice.

The Crustaceans perceive the existence of bodies at a distance by the medium of odorous particles emitted from these bodies. Many of the known habits of these animals, and the certainty with which they are attracted by baits placed in close traps from which the light is excluded, do not allow us to entertain any doubts upon this point; but we are reduced to conjecture when we are required to point out the precise seat of the organ of *smell*. The horny appendages named antennæ are certainly not it, as M. de Blainville imagined;* and the opinion of M. Rosenthal,† who ascribes the function to a cavity which he discovered at the base of the first pair of antennæ, requires to be supported by direct experiment.

Hearing, at least in a great number of species, resides in a particular apparatus perfectly well known. It (*fig.* 396) is found in the inferior surface of the head, behind the antennæ of the second pair, or upon the first basilar articulation of these antennæ themselves‡ (*fig.* 396, *a*). It consists in the River-crab of a small bony tubercle pierced at its summit by a circular opening, upon which is stretched a thin elastic membrane, which Scarpa has compared to that of the tympanum, or of the fenestra ovalis of the vestibule in the higher animals. Behind this membrane there is a membranous vesicle filled with fluid, into which a branch of the antennary nerve is observed to plunge. Above this organ there is another of a glandular appearance, the intimate relations of which with the apparatus we have just described might lead to the belief that it was not unconnected with the sense of hearing. In the Palinurus it communicates with an opening which is pierced through the centre of the membrane that closes the auditory tubercle in front.

Fig. 396.



The membrane in the greater number of the Brachyura is replaced by a small moveable osseous disc, which in the Maja and some others presents a pretty broad bony plate (*fig.* 397) at its posterior edge, detaching itself at right angles and running upwards towards the glandular organ already mentioned. Near its base this lamellar prolongation is pierced with a large oval opening, over which there is stretched a thin and elastic membrane which might be named the *internal auditory*

Fig. 397.

Auditory disc of the Maja Squinado separated from the rest of the apparatus.

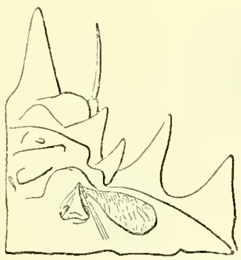
* Principes d'anatomie comparée, t. i. p. 338 et 339.

† Reil's Archiv. und Treviranus's vermischte Schriften, 2ter Band. 2tes Heft.

‡ *Minasi*, Dissertazioni di timpanetti del'udito scoperti nel Granchio paguro. *Scarpa*, De structura fenestræ rotundæ, &c. Anat. observ. 4to. Mutin. 1772; Anat. Disq. de Auditu et Olfactu, fol. Ticin. 1789. *Cuvier*, Leçons d'anatomie comparée, t. ii. *Milne Edwards*, Histoire naturelle des Crustacés, t. i. p. 123.

membrane, near to which the auditory nerve appears to terminate. This small bony lamina, which is moved by minute muscular fasciculi, recals in some measure the stapes of the human ear. Under the anterior edge of the external opening of the ear which is closed by this bony disc (*fig.* 398), is seen a small

Fig. 398.



Auditory apparatus of the Maja in its natural position, showed by removing the carapace and the viscera.

lamina parallel to the internal auditory membrane; and when the anterior muscle of the ossiculum contracts so as to bring, in a slight measure, the whole of this little apparatus forwards, the membrane of which mention has just been made rests upon the bony prolongation, and is made tense in a continually increasing degree; and from the experiments of M. Savart we know that all increase in the tension of thin membranes lessens their disposition to be thrown into vibration;* consequently in undergoing such a modification, the kind of tympanum described must serve to moderate sounds of too great intensity, in their passage to the acoustic nerve. In other respects it is evident that the mechanism described presents the most forcible analogies with what we observe in the human ear, and that the ossiculum auditus here stands in lieu of the chain of small bones which exists in the organ of hearing arrived at its highest point of development.

The presence of the long rigid stem formed by the antennæ of the second pair, and its immediate communication with the organ of hearing cannot, it might have been presumed *à priori*, be unimportant as regards the perception of sound; and this is found to be the case in fact;† for from the beautiful experiments of M. Savart we learn that the addition of a rigid stem is sufficient to render certain vibrations perceptible, which, without this kind of conductor, are altogether inappreciable.

The auditory apparatus of the Crustacea consequently consists essentially of a cavity full of fluid, to which a nerve adapted to perceive sonorous impulses is distributed; which elementary and essential apparatus is assisted in its functions by certain special organs, such as elastic membranes and rigid stems, calculated by their nature to vibrate under the action of sonorous undulations.

We have still to speak of the organ of *sight*. With the exception of certain parasitic species, the faculty of perceiving the existence of external objects by the medium of light is possessed by the whole class of Crustacca, and is found dependent on a particular organ of a considerably complicated structure situated in the head, towards its anterior aspect, superiorly or on the sides. Even the exception which has been made is merely accidental, as it were; for in the earliest periods of their existence the parasitic Crustacea also possess eyes, and it is only as an effect of the kind of metamorphosis which these animals experience that the organs of vision disappear.

The eyes in insects are simple or compound; but this division is inadequate to give us any proper idea of the various forms under which these orgaus present themselves to our observation in the Crustacca, and into the study of which we shall, therefore, enter with some attention to detail.*

The least complex form under which the eyes of the Crustacea occur is that which has been designated under the name of *Stemmata*, *smooth eyes* or *simple eyes*. The structure of these does not differ essentially from that observed among the higher animals. We distinguish, in the first place, a *transparent cornea*, smooth and rounded, which is in fact nothing more than the general tegumentary membrane modified in a particular point. The internal aspect of this cornca is in immediate contact with a crystalline lens, generally of a spherical form; this, again, is in contact posteriorly with a gelatinous mass analogous to the vitreous humour, and this mass in its turn is in contact with the extremity of the optic nerve. A layer of pigmentum thick and of a very deep colour, envelopes the whole of these parts, lining the internal wall of the globe of the eye up to the point at which the cornea begins to be formed by the thinning of the tegumentary envelope become transparent. This is what we observe in a limited number of the Crustacea, among which we may mention the Limuli, the Cyamæ, and the Apus. The number of these simple eyes never exceeds two or three.

A step in the complexity of the organ of sight is presented to us in the eyes of the Nebalia, Branchipus, and Daphnia. In these, behind the cornea, which externally presents no trace of divisions, a variable number of small crystalline lenses and vitreous humours are found, each included in a kind of sac or pigmentary cell, and terminating by coming

* Recherches sur les usages de la membrane du tympan et de l'oreille externe, Journal de Physiologie de Magendie, t. iv.

† *Strauss-Dräckheim*, Considerations générales sur l'anatomie des Crustacés, p. 419.

* On the structure of the eyes, vide *Swammerdam*, in the Collection Academique, partie étrangère, t. v. p. 170. *Cavolini*, Memoria sulla generazione dei Pesci et Dei Granchi. *Strauss*, op. cit. *J. Müller*, Zur vergleichenden Physiologie des Gesichtsinnes etc. Ann. des Sciences Naturelles, t. 17. *Milne Edwards*, Hist. Nat. des Crustacés, t. i. p. 114.

immediately into contact with the optic nerve. These eyes are obviously made up by the conjunction of several stemmata under a common cornea. The Apus, besides its pair of simple eyes, presents another compound pair, behind and at some distance from these.

The Amphihoë Prevostii and some other Edriophthalmians present the transition from the form last described to that of truly compound eyes, having distinct facets. The cornea in these is formed of two transparent laminæ, the external of which is smooth and without divisions, whilst the internal is divided into a variable number of hexagonal facets, each of which is a distinct cornea, superposed upon such a conical crystalline lens, as we shall have occasion immediately to describe when speaking of *compound eyes properly so called*, or *eyes with simple facets.*

In these the two membranes, external and internal, the union of which constitutes the cornea, present simultaneously the division into facets, each of which forms anteriorly an ocular compartment proper to it. These facets, always hexagonal in insects, are of various forms in the Crustacea: thus in the Astacus fluviatilis, the Peneæ, the Galatheæ, and the Scyllari, they are square (*fig.* 399), whilst the Paguri, the Phyllosoma, the Squillæ, the Gebiæ, the Callianassæ, and the Crabs, have them hexagonal (*fig.* 400). The crystalline that succeeds them immediately is of a conical form, and is followed by a vitreous humour having the appearance of a gelatinous filament, adhering by its base to the optic nerve. Each of the columns thus formed is, moreover, lodged within a pigmentary cell, which likewise covers the bulb of the optic nerve. But the most remarkable circumstance is, that the large cavity within which the whole of these parallel columns, every one of which is in itself a perfect eye, are contained, is closed posteriorly by a membrane, which appears to be neither more nor less than the middle tegumentary membrane, pierced for the passage of the optic nerve; so that the ocular chamber at large results from the separation at a point of the two external layers of the general envelope.

Fig. 399.

Fig. 400.

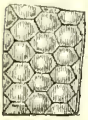
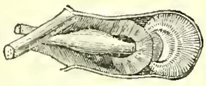


Fig. 401.



Longitudinal section of the Eye of the Lobster.

The gelatinous or vitreous elongated processes which succeed the conical crystallines have been looked upon by several anatomists as ramifications of the optic nerve; but we do not imagine that they are so in reality. In the Lobster, for instance, we have even seen the surface of the bulb isolated from the masses in question, divided into compartments corresponding to those of the cornea itself, and lined with a layer of pigmentum perfectly distinct.

The most remarkable modification of facetted eyes consists in the presence of a kind of supplementary lens, of a circular shape and set within the cornea in front of each proper crystalline lens (*fig.* 402). These small lenticular bodies exist independently, and are perfectly distinct from the small corneal facets. In some cases they might be mistaken (in the Idoteæ, for example, where they may be perceived singly, and with their distinct circular forms), and the incautious observer led to conclude that the corneal facets are merely these lenticular bodies so much enlarged that their hexagonal or square forms result from their agglomeration in a point; but there are Crustacea, such as the Callianassæ, in which these two elements of the external cornea may be perfectly distinguished, the lenticular body being of insignificant dimensions and occupying the centre of the corneal facet only (*fig.* 402). In general, however, the diameter of the lenticular body is equal to that of the corneal facet itself, so that their edges blend. Farther, the lenticular bodies are most commonly evolved in the substance of the cornea; but there are cases in which, under favourable circumstances, they may be detached from it.

Fig. 402.

Although the existence of these different modifications must not be understood as being exclusive, inasmuch as there are certain Crustacea which exhibit more than one of them at the same time, for instance, *stemmata* and *compound eyes*, the latter only are the species of visual organ encountered in the great majority of cases. Their general number is two; but these are occasionally united, so as to form a single mass, and make the animal appear at first sight as if it had but a single eye. This peculiarity of organization can even be followed in the Daphniæ, in the embryo of which the eyes are first seen isolated; with the progress of the development, however, they are observed gradually to approach each other, and finally to become united. Stemmata are always immoveable and sessile; the compound eyes with smooth corneæ, however, although in the majority of cases they present the same disposition, now and then occur moveable: sometimes they are supported by a pedicle, moveable in like manner, and provided with special muscles. The eyes with facets present the same modifications, and even supply important characters in classifying these animals: thus in the Edriophthalmia the eyes are always immoveable and sessile, (*fig.* 403,) whilst in the Decapoda and the Stomapoda (*fig.* 404) they are supported upon moveable

Fig. 403.

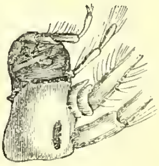
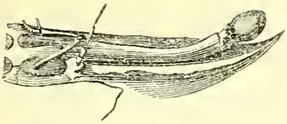


Fig. 404.



stems of very various lengths, and which every consideration leads us to view as the limbs or appendages of the first cephalic ring. It sometimes even happens (*fig.* 404) that in these animals, between the outer edge of the carapace and the base of the antennæ, there occurs a furrow or cavity within which the eyes may be withdrawn or laid flat, so as to be out of the way of injury; this groove or cavity is generally spoken of under the name of the *orbit*.

§ 3. *Apparatus of Nutrition.*

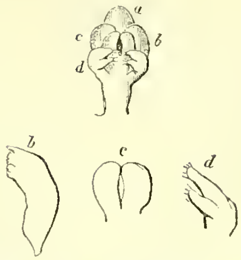
In the study of this apparatus we shall have to consider successively the organs of digestion, of circulation, of respiration, and of secretion.

A. *Apparatus of digestion.*—The organs concerned in the digestion of the food among the Crustacea may be divided into three orders, according to the functions they fulfil, to wit, 1st, the apparatus for the prehension and mastication of the food; 2nd, the alimentary canal; 3rd, the various secreting organs associated with the intestine.

The Crustacea are divided into two grand sections in conformity with their habits and the nature of their food:—the *masticators*, which generally live apart from their prey, pursue it, and seize it in proportion as they are admonished by their wants or appetite to do so; and the *suckers*, considerably fewer in number, and which in their state of perfect growth live almost invariably attached to their prey without executing any other motions than such as are performed by the latter.

The *masticating* Crustacea being the highest in point of organization, we shall commence our description with them,* and we shall even select for our particular consideration the species among these which have the class of organs about to be investigated of the most complex structure, namely, the Decapoda brachyura. In these animals the mouth is constantly situated on the inferior surface of the cephalic portion of the body. Two *lips* close it anteriorly and posteriorly; the *upper lip* or *labrum* (*a*, *fig.* 405) is a median piece in the form of a simple fold, and the *lower lip* or *languette* (*c*) is for the most part bifid. Between these two pieces and on their sides are the *mandibles*, (*fig.* 406,) appendices of the fourth cephalic ring, modified so as to serve for mastication. As in the whole tribe of articu-

Fig. 405.

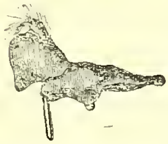


Masticatory Organs of the Phyllosoma.

a, upper lip; *b,* mandibles; *c,* lower lip; *d,* maxillæ.

lated animals, these organs act laterally, and not upwards and downwards in the line of the axis of the body as in the vertebrate series universally. They do not vary much in point of form among the Decapoda; in almost every one of these they are seen possessed of a principal part terminated by a cutting edge, or a surface adapted for trituration; and an appendage which appears to fasten the food and keep it steady during the process of mastication. The mandible itself, which is of extreme hardness, appears to be neither more nor less than the basilar piece of the member or appendage, of great strength and toothed. The articulated *palp* which it supports, in this mode of viewing the structure, would turn out to be a mere continuation of the *stem (tige)*, and not a proper palp, as its name seems to imply, but which it has only acquired from its resemblance to the appendage to which the term of right belongs.

Fig. 406.



Such is the structure of the mouth among a certain number of the inferior Crustacea; but among those to which we now turn our attention, we remark an addition of as many as five pairs of modified appendages situated behind the under lip, and all subservient to the prehension and the mastication of the food. The two first (*figs.* 406 and 407) are the most constant; and even when we get low in the series, and they have lost their special functions, they can still be traced, although of course only in a rudimentary state. When well developed they are without palps and are designated by the name of *jaws*. The three other pairs, again, soon cease to appear as part of the implements of digestion, in order to show themselves among the instruments of locomotion; sometimes, however, they seem to serve for both kinds of function, a circumstance which has

Fig. 407.

* On this subject consult *Savigny* Mémoires sur les Animaux sans Vertèbres, 1re fascicule; *Latreille*, Hist. Nat. des Crustacés et Insectes, &c.; *Cuvier*, Règne Animal; *Desmarest*, Considérations sur les Crustacés; *Milne Edwards*, Hist. Nat. des Crustacés, t. i. p. 61.

led to their ordinary denomination of *maxillary limbs* or *feet* (*figs.* 408, 409, 410.)

Fig. 408.

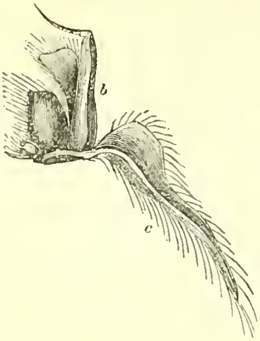
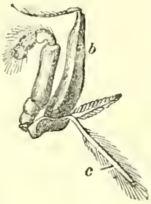


Fig. 409.



The forms and dimensions of these organs vary considerably, and are obviously in harmony with their uses; they are by so much the shorter and flatter as they are more peculiarly apportioned to the oral apparatus, a disposition which is nowhere more conspicuously displayed than among the short-tailed Decapods, in which they resemble horny laminæ, armed with teeth or serræ of various sizes, and supporting an articulated palp (*b*, *fig.* 408) as well as a *flabelliform* or *whip-shaped appendage* (*c*), which penetrates into the interior of the branchial cavity. The last pair of all (*fig.* 410) presents

Fig. 410.

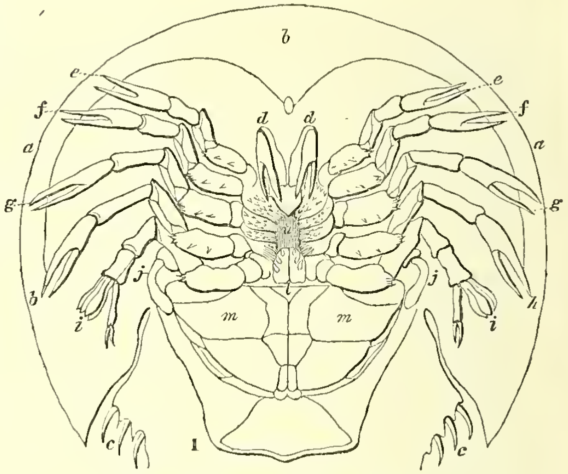
itself under the shape of two thin and much expanded laminæ which serve as a kind of broad operculum to cover the whole of the oral apparatus.

Starting from this complication of structure, the greatest in the series, we shall see the apparatus degenerating by successive degrees, at the same time that in any given group its composition presents much less of constancy or regularity. The Sergestes among the Decapods have one pair of maxillary feet fewer than the highest number; the Edriophthalmians have no more than a single pair, whilst in the Thysanopoda and the generality of the Stomapoda the number of oral appendages amounts to three pairs, and in the Phyllosoma to two pairs only.

To conclude, the Limuli, a group of Crustaceans of the most singular conformation, are at the bottom of the scale in this respect; for in them (*fig.* 411) the anterior ambulatory extremities themselves surround the mouth, and their basilar articulations perform the office of jaws.

The organs of which we have just made mention, are, according to the modifications they undergo, adapted in a more or less especial manner to seize, to hold fast, and to comminute the alimentary matters upon which the animal lives. Moreover the thoracic extremities in many species are themselves calculated to accomplish one or all of these offices with various degrees of success, according to their form, their extent, and the mode in which

Fig. 411.

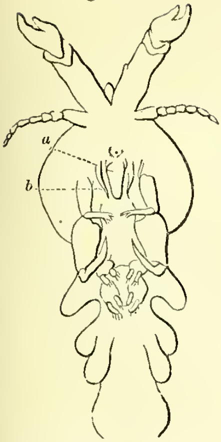


Limulus polyphemus, (ventral aspect.)

a, carapace; *b*, frontal portion of the carapace; *c*, thorax; *d*, chelifera; *e, f, g, h, i, j*, legs, the basilar portions of which surround the mouth and act as mandibles; *l*, under-lip; *m*, branchial or lamelliform appendages; *n*, mouth.

they are terminated. The most favourable disposition to these ends is observed in the lobsters, crabs, &c.; in a word in a very great number both of the short and long-tailed Decapods, in which the anterior thoracic extremities terminate in pincers of greater or less strength, armed with teeth and sharp hooks which give them increased powers of prehension. This form results mainly from the state of extreme development in which the penultimate articulation frequently occurs, and its assumption of the shape of a finger, by the prolongation of one of its inferior angles. Against the finger-like process thus produced, which is of great strength and quite immoveable, the last articulation can be brought to bear with immense force, as it is put into motion by a muscular mass of great size, and in relation with the extraordinary size of the pe-

Fig. 412. *Fig*. 413. *Fig*. 414. *Fig*. 415.



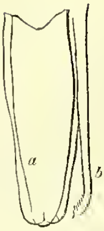


Fig. 412, *Ventral aspect of the cephalo-thoracic portion of the Dichelestion.*
a, trunk or sucker; *b*, maxillæ.

Fig. 413, *The trunk or sucker magnified.*
a, the labrum; *b*, the mandibles.

Fig. 414 & 415, *The maxillæ.*

nultimate articulation (the *claws, pincers,* or *cheliferous extremities).*

The extremity occasionally terminates in two articulations presenting no kind of unusual development, but the last of which, terminated by a sharp point and armed with teeth or serræ, returns upon the preceding one, so as to form a kind of hook or pincer, opening in the opposite direction, (the sub-cheliform extremities of the *Squillæ* and *Crevettinæ).* Lastly, these extremities frequently terminate in a simple acute angle of which the animal can make no use save in locomotion.

In the *Sucking Crustacea,* which live parasitically on other animals and feed by sucking their blood, the structure of the oral apparatus is extremely different.* Certain pieces which must be considered as analogous to the *labium* and *languette,* are elongated, so as to form a trunk or cylindrical tube, of variable length, adapted for sucking, and in the interior of which are lodged the mandibles, now prolonged so much that they form two slender and pointed processes the extremities of which serve as a lancet. The appendages which in the masticating Crustacea constitute the jaws, here continue rudimentary, and the three pairs of limbs which in the Decapoda complete the oral apparatus, under the name of maxillary extremities, are here transformed into organs of prehension, of different forms, by means of which the parasite attaches itself to its victim.

In the whole of the Crustacea the intestinal canal presents two openings, the mouth and the anus, always separated from each other by the whole length of the body.

The mouth is the mere anterior and outward expansion of the œsophagus; it is furnished with nothing that can properly be compared to a tongue; the horny and lamellar organ which writers have sometimes spoken of under this name is nothing more than the lower lip, which has already been described.

The œsophagus itself is short; it rises vertically and runs to terminate directly in the stomach. Its general structure, as well as that of the stomach and whole of the intestinal canal, bears a very close resemblance to what we observe among the superior animals. They each consist of two membranous layers separated by one of muscular fibres, always of greatest thickness in those points in which the most energetic contractions take place, and especially at the entrance into and passage out of the stomach.

The stomach is of a globular form, and of very great capacity; it fills a considerable extent of the cephalic cavity, and presents two portions very distinct from one another; the cardiac region, vertically surmounting the mouth and œsophagus, the axis of which is lost in its own; and the pyloric region, situated behind the former, and forming a right angle with it.

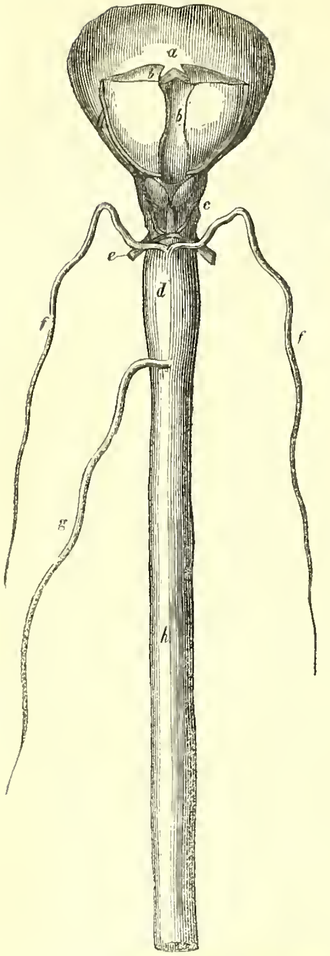
But the most remarkable feature presented by the stomach of the Crustaceans is the very complex masticatory apparatus it contains. This consists of a considerable number of pieces, the form and disposition of which vary, and are always singularly in harmony with the kind of food taken and the general habits of these animals. The apparatus, as well from the important office it fulfils, as from its being no where else encountered in so perfect a state of development, were worthy of a description which would swell this article to too large a size; we shall therefore be brief, and merely state generally that it consists of a great number of pieces, so connected as to constitute a kind of solid frame armed internally with tubercles or sharper teeth situated around the pylorus, and capable of being moved so as to bruise or tear in piec the alimentary-matters subjected to their action, and as they are about to pass through this opening.*

The different pieces composing this apparatus vary considerably in the different genera,

* See our "Recherches sur l'Organization de la Bouche des Crustacés Suceurs," Ann. des Sc. Nat. t. 28; Burmeister's Beschreibung einiger neuen schmarotzer Krebse, in the Acta Acad. Cæs. Leop. Nat. Cur. vol. xvii. p. 1.

* Vide Cuvier, Leçons d'Anatomie Comparée, t. iv. p. 126, and Milne Edwards, Hist. Nat. des Crustacés, t. i. p. 67, for further details.

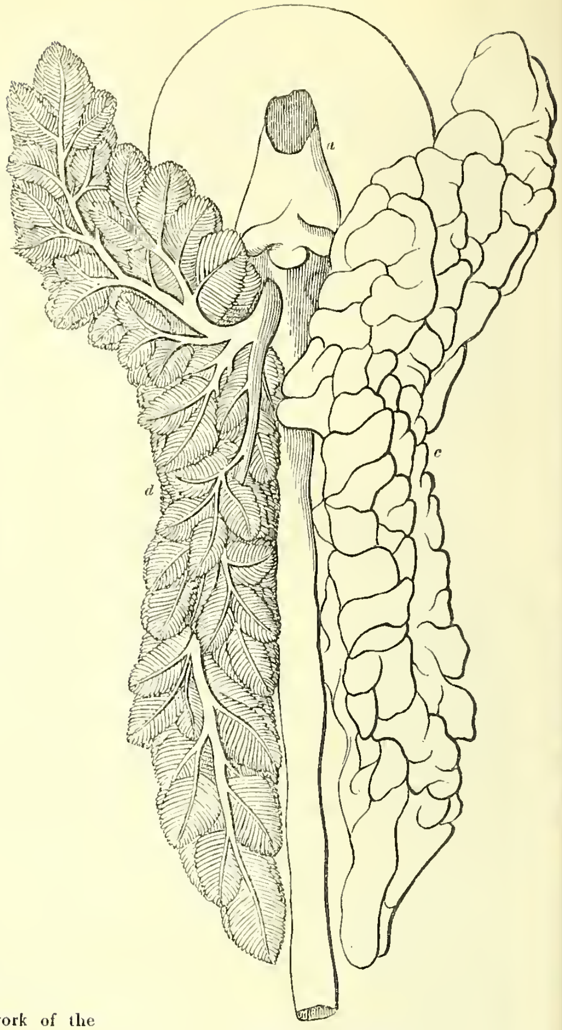
Fig. 416.



Digestive canal of the Maja.

a, Cardiac portion of the stomach.
b, b, Upper portion of the frame-work of the stomach.
c, Pyloric portion of the stomach.
d, The small intestine.
e, Termination of the biliary ducts.
f, Anterior appendages of the intestine.
g, Posterior appendages.
h, Rectum.

Fig. 417.



Liver of the Lobster.

a, stomach; *b*, intestine; *c*, left lobe of the liver in its natural state; *d*, right lobe dissected, so as to show its structure and the disposition of the biliary ducts.

and even in the several species of the same genus. Still every one of them may be demonstrated with a little care, in the whole of the Brachyura and of the Macroura. They are less numerous, and are singularly modified in proportion as we recede from these types. In the Squilla mere vestiges only of the apparatus are found in two semicorneous pieces covered with rounded projections; and its functions are performed by a branch of each mandible which penetrates even to the pyloric orifice of the stomach.

The intestine extends from the pylorus to the anus without curve or convolution in its course (*fig.* 416, *d*, *h*). In the superior Crustacea it may be distinguished into two portions, one of which may be named the *duodenum*, the other the *rectum*. These two portions where they occur vary extremely both in their nature and in their relative lengths. Sometimes they are separated by a valve (Lobster) corresponding internally to a circular external elevation; but still more frequently their respective limits are not obviously marked, and among the whole of the inferior members of the family the intestinal canal is entirely cylindrical, and perfectly identical in its constitution through its whole length. The anus is constantly seated in the last ring, and is closed by certain muscular fibres which perform the office of a sphincter.

The biliary apparatus of the Crustacea is of very large size in the Decapoda. The liver is symmetrical (*fig.* 417), and consists of two halves generally separate one from another, and the whole organ is made up of an agglomeration of cœcums, which by one of their extremities empty themselves into excretory ducts. These by their union form larger and larger trunks, and the secreted fluid or bile is finally poured by a double channel into the pyloric portion of the stomach. The liver is found to undergo extensive modifications as it is examined in individuals lower and lower in the series; in the Edriophthalmians, finally, we discover nothing except three pairs of biliary vessels analogous to those of insects.

The liver is not the only secerning organ whose product is poured into the intestine. On each side of the pyloric portion of the stomach, we observe two blind tubular cavities narrow and much elongated in their form, which pour out a whitish fluid (*fig.* 416, *f*, *f*); and at the point of conjunction of the two portions of which the intestine frequently consists, as has been said, there is a third tubular cavity or vessel in all respects similar to these two (*fig.* 416, *g*). These tubuli are all wanting in the Astacus fluviatilis, and in the Astacus marinus the single posterior tubulus is the only one found. Nothing positive is known with regard to the uses of the fluid secreted in these tubuli.

To conclude, there are two organs of a green colour situated on either side of the œsophagus, the structure of which is glandular, and which appear to bear some analogy to the salivary glands.

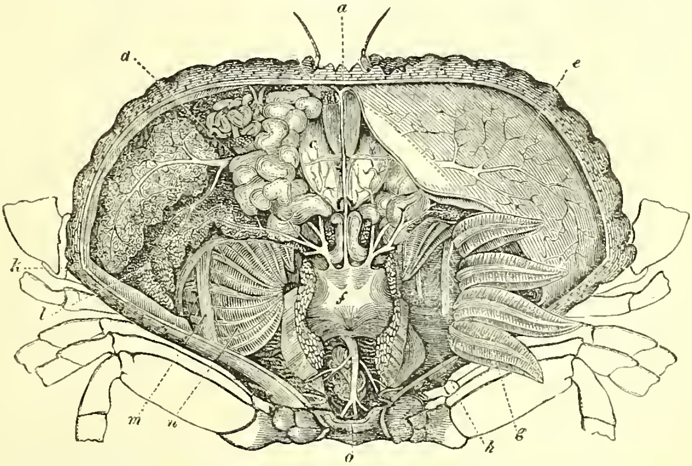
B. *Of the blood and circulation.*—We are altogether without positive information as to the mode in which the nutritious fluid, elaborated by the process of digestion, passes from the intestinal canal into the torrent of the circulation. Hitherto no chyliferous vessels have been detected, and we are therefore led to believe that it is by imbibition that the transference takes place from the intestine to the bloodvessels in the Crustacea.

The blood of the Crustacea is a colourless, or slightly bluish coloured fluid, holding an abundance of circular-shaped globules in suspension. It is extremely coagulable. Its chemical composition has not been investigated.

This nutritious fluid is put into motion by a heart, and circulates through a vascular system of great complexness. Willis,* Swammerdam,† Cuvier,‡ Desmarest,§ and several others have given a description of this system; but there are still innumerable points upon which opinions remain different. The following are the conclusions to which M. Audouin and I have come from a careful study as well of the anatomical disposition of the circulatory apparatus of the Crustacea, as of the progress of the blood through its interior.||

The circulation of the blood in these animals is accomplished in a manner very similar to what takes place in the Mollusca. The blood pushed forward by the heart is distributed to every part of the body, from whence it is returned into large sinuses situated at no great distance from the base of the branchiæ; from these sinuses it is sent on to the respiratory apparatus which it traverses, and from which it then finds its way to the heart, to recommence the same circle anew. The heart is consequently aortic and single.

Fig. 418.



Viscera of the Cancer Pagurus.

f, heart; *a*, ophthalmic artery; *o*, abdominal artery; *c*, stomach; *e*, skin; *g*, branchiæ, inverted to show the efferent vessels; *h*, vault of the flancs; *n*, branchiæ in their natural position; *m*, flabellum; *l*, liver; *k*, testicles.

* De anima brutorum, caput tertium, p. 16.

† Collect. academique, partie étrangère, t. v. p. 126.

‡ Leçons d'Anatomie Comparée, t. iv. p. 407, et Règne Animal, 1re ed. t. ii. p. 512, et t. iii. p. 5.

§ Considerations sur les Crustacés, p. 57.

|| Recherches anatomiques et physiologiques sur la Circulation dans les Crustacés, Ann. des Sc. Nat. t. 11.

The heart is always found in the median line of the body, and lying over the alimentary canal near the dorsal aspect. Its form is various; in the Decapods it is nearly square, and lies in the middle and superior part of the thorax, being separated from the carapace by tegumentary membranes only, and may be seen in the space included between the two vaults of the flancs. In structure it appears to be composed by the interlacement of numerous muscular fibres, fixed by their extremities to neighbouring parts and passing to some distance over the aggregate at either end, so that the whole organ brings to mind such a figure as would be formed by the superposition of a number of stars the rays of which do not correspond. In the other orders this general form of the heart varies considerably, from the figure of an oblong square of rather inconsiderable size, as it occurs in the Decapoda (*fig.* 418, *f*), to that of a long cylindrical vessel extending through the whole length of the body as it appears in the Stomapoda (*fig.* 419), and the Edriophthalmians. In the former of these it gives origin to six vascular trunks, three of which issue from the anterior edge, and three from the posterior surface; each of the six openings is closed by a valvular apparatus which prevents the regurgitation of the blood.

The first of the three anterior vessels is situated in the median line and is distributed to the eyes, in consequence of which we have entitled it the ophthalmic artery (*a*, *fig.* 418). Lodged within the substance of the general tegumentary membrane, it continues its course without undergoing any subdivision along the median line through the whole length of the thorax, until, arrived opposite the eyes, it subdivides and terminates in two branches which penetrate the ocular peduncles.

On the two sides are the two *antennary arteries*. They run obliquely towards the antennæ, sending off numerous branches to the tegumentary membrane in which they are at first lodged; they then plunge more deeply, sending branches to the stomach and its muscles and to the organs of generation, between which they insinuate themselves by following the folds of the same membrane which parts them. Lastly, each of these vessels subdivides into two branches, one of which proceeds to the internal and the other to the external antenna.

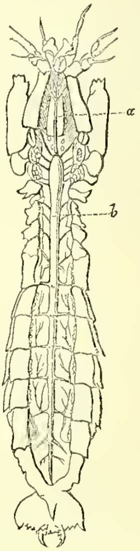
Two *hepatic arteries* arise from the fore part of the inferior surface of the heart, and penetrate the liver, there to be ramified; but they are only found double and distinct from one another so long as the liver is met with divided into two lobes, as it is in the River-crab and Lobster.

From the posterior part of the same surface of the heart there proceeds a large trunk, which, from its importance, might be compared with the aorta. This is unquestionably the vessel which many authors have spoken of as a great vena cava: we have entitled it the *sternal* artery. It bends forwards, giving origin to two *abdominal* arteries (*o*, *fig.* 418), dips into the sternal canal, distributing branches to the different thoracic rings, as also to the five first cephalic rings, which it passes over in its course. Meeting with the œsophagus it bifurcates, but still sends branches to the mandibles and the whole of the anterior and inferior parts of the head.

The bulb presented by the sternal artery at its origin, in the Macroura, is the part which Willis characterized as the *auricle* of the heart. As concerns the two abdominal arteries, which may be distinguished into *superior* and *inferior*, and which arise from the kind of cross which it forms almost immediately after its exit, they are in precise relationship in point of size with the magnitude and importance of the abdomen itself. In the Brachyura they are mere slender twigs; in the Macroura, on the contrary, they are capacious stems, and the inferior of the two sends branches to the two posterior pairs of thoracic extremities.

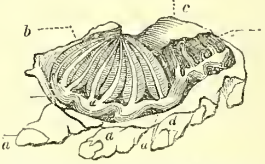
The disposition of the three first vessels is the same in the Stomapoda as in the preceding species; but the great vessel which represents the heart being extended through the whole length of the body, supplies immediately other arterial branches in pairs, and in number equal to those of the rings.

Fig. 419.



Arterial system of the Squilla.
b, heart; *a*, anterior artery.

Fig. 420.



Venous system of the Maja.

a, venous sinuses; *b*, branchiæ; *c*, vault of the flancs partly taken away; *d*, legs.

The blood returns from the different parts of the body by *canals*, or rather *vacuities* among the tissues, (for they have no very evident appropriate parietes,) which terminate in the *venous sinuses*, situated close to the branchiæ.

In the short-tailed Decapoda we find no more than a double series of these sinuses, included within the cells of the flancs above the articulations of the extremities. They communicate with one another, and they appear to have no parietes other than laminæ of cellular membrane of extreme tenuity which cover the neighbouring parts. Each of them, nevertheless, receives several venous conduits, and gives origin at its superior and external part to a vessel which, traversing the walls of the flancs at the base of the branchiæ, conducts the blood to the latter organs. This is the external or afferent vessel of the branchiæ.

We find the same lateral venous sinuses in the Macroura; but instead of communicating with one another athwart the thoracic septa, as is the case in the Brachyura, they all empty themselves into a great median vessel, which is itself a venous sinus, and occupies the sternal canal. In the Squilla this sinus is almost the only vessel which serves as a reservoir to the venous blood.

The blood, after having been arterialized in its passage through the capillaries of the branchiæ, is poured into the *efferent vessel*, which, as we shall immediately have occasion to see when treating of the respiratory process, runs along the internal surface of each branchia. It enters the thoracic cells in the same manner as the afferent vessel passed out from them, bends upwardly under the vault of the flancs, and thus takes its course towards the heart. It is to this portion of the canal that we have given the name of *branchio-cardiac vessel.*

The mode in which the blood enters the heart is still a subject under discussion. Our inquiries lead us to believe that this fluid, poured by the branchio-cardiac canals into a sinus situated on each side of the heart, penetrates this organ by means of certain openings situated in those parts of its substance which are directly opposite to the canals mentioned. But Messrs. Lund and Strauss imagine that the blood is effused as it were into the pericardium (which is named *auricle* by the latter anatomist) to penetrate from thence by openings situated on the superior surface of the heart.* These openings, however, we conceive to be closed in the natural state by means of a membrane, and it is also worthy of remark that the writers just cited were unacquainted with the lateral openings which establish a much more direct communication with the interior of the organ. We must also add that the celebrated John Hunter, whose labours upon this subject have hitherto remained unknown to the world, but which have very recently been given to the public by Mr. Owen, had long ago ascertained the existence of the venous sinuses and of the lateral openings of the heart, although he seems to have thought that the circulation was not complete in the manner we have described it.*

In the most inferior groups of the class of Crustaceans the apparatus of the circulation becomes much less perfect, and even seems to disappear entirely in the last of the Haustellate tribes. In the Argula, for instance, there still exists a heart, but the arteries as well as the veins appear to be nothing more than simple lacunæ, formed in the interstices between the different organs; and in the Nicothoa, &c. no distinct trace of any portion of a circulatory system has yet been discovered.

C. *Of the respiration.*—The Crustacea, like all the other tribes especially formed for living under water, respire by means of certain parts of their external covering modified in its structure in order to fit it for this function, and known under the name of *branchiæ.* This character is even so completely inherent in the organic type proper to this class, that it is still preserved in certain species which live on the land and not in the water.

Nothing, however, can be conceived more various than the form and disposition of the organs of the branchial respiration among these animals: in some the function is performed by an extremely complex apparatus, consisting in great part of organs created expressly for this end; in others it is delegated to certain appendages which do not exist for the office exclusively, but are rather turned from their more ordinary and obvious uses to subserve this important function. In others still, we neither discover special organs of respiration nor other parts whose structure fits them evidently to supply the place of branchiæ; in these cases we can only suppose that the oxygen held in solution by the water acts upon the nutritious fluid of the animal by the intermedium of the entire tegumentary covering.

Let us first review the respiratory apparatus in its state of greatest complexity, but commencing with it in the embryo and following it in its progressive development, in order that we may be the better prepared to compare it with those forms which will be presented to us among species less elevated in the series of the Crustaceans.

In the earliest periods of embryotic life of the common Astacus fluviatilis, we discover no trace of branchiæ; but at a somewhat more advanced stage of the incubation, though still before the formation of the heart, these organs begin to appear. They are at first small lamellar appendices of extreme simplicity, attached above the three pairs of maxillary extremities, and representing the flabelliform portions of these limbs. Soon these lamellar appendages elongate and divide into two halves, one internal, lamellar and triangular, the other external, small and cylindrical; lastly, upon the surface of

* *Lund,* Doutes sur l'existence du systeme circulatoire dans les crustacés, Isis 1825. *Strauss,* Anat. comp. des Animaux articulés.

* Catalogue of the Physiological Series of Comparative Anatomy, contained in the Museum of the Royal College of Surgeons, vol. ii.

this, striæ are observed to appear, which are the rudiments of the branchial filaments. During this interval the thoracic extremities have become developed, and above their bases other branchiæ have made their appearance, presenting in the beginning the form of tubercles, and subsequently that of stilets; smooth and rounded on their surface, but by-and-by becoming covered with a multitude of small tuberculations, which by their elongation are gradually converted into branchial filaments similar to the preceding. During this period of the development of the branchiæ these organs are applied like the extremities to the inferior surface of the embryo; but they subsequently rise against the lateral parts of the thorax, become lodged within a cavity situated under the carapace, and thus are no longer visible externally.

The cavity destined to protect in this manner the branchial apparatus, is neither more nor less than an internal fold of the common tegumentary membrane. It shows itself first under the guise of a narrow groove or furrow, which runs along the lateral parts of the thorax below the edge of the lateral piece of the carapace. This longitudinal furrow is not long of expanding, and becomes consolidated by its superior edge with the internal surface of the carapace, which, by being prolonged inferiorly, constitutes the external wall of a cavity, the opening of which, situated above the base of the extremities, becomes more and more contracted, and ends by being almost entirely closed. The space in this way circumscribed encloses the branchiæ, and constitutes what is called the respiratory cavity of the Decapod Crustaceans.

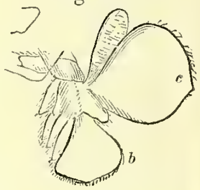
From what has just been said, it would appear that the embryo of the Astacus fluviatilis presents four principal periods with reference to the state of the respiratory apparatus; 1stly, that which precedes the appearance of this apparatus; 2dly, that during which the branchiæ are not distinguishable from the flabelliform appendages of the extremities, or in which it consists of simple lamellar or stiliform processes, which appear as mere processes of other organs especially dedicated to locomotion or to mastication; 3dly, that characterized by the transformation of these extremely simple appendages into organs of a complex structure, entirely distinct from the extremities, but still entirely external; 4thly and lastly, that during which the branchiæ sink inwards and become lodged in a cavity especially adapted for their reception, and provided with a particular apparatus destined to renew the water necessary to the maintenance of respiration.

If we now turn to the examination of the apparatus of respiration in the different groups in which it exhibits important modifications, we shall, in the series of Crustaceans, encounter permanent states analogous to the various phases through which we have just seen the apparatus passing in the most elevated animals of the class.

And, in fact, the first period which we have particularized above in the embryonic life of the Decapod is exhibited in the permanent condition of some inferior Crustaceans, in which not only is there no special organs for respiration, but in which none of the appendices occur with such modifications of structure as would fit them to become substitutes for the branchiæ, in which, consequently, the process of respiration, that is the aeration of the blood, appears to take place over the surface of the body at large. The greater number of the Haustellate Crustacea, of the Entomostraca properly so called, of the Copepoda, and even of the Phyllosomata, appear to belong to this type of organization.

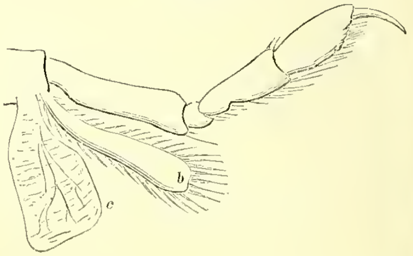
A state analogous to that which characterizes the second period in the development of the embryo of the Decapod, is presented to us in a large number of other Crustaceans, the organization of which is more perfect than that of the animals of which mention has just been made, we mean the Branchiopoda and Edriophthalmia, in which, although we do not yet find branchiæ properly so called, that is to say, organs peculiarly devoted to respiration, we discover certain appendages of the extremities which serve for this function. In the Branchiopoda (*fig.* 421) the whole of the thoracic extremities present a lamellar conformation, and the two external portions of the appendages corresponding to the palp and flabellum (*fouet*), form membranous vesicles of a flattened form, soft to the touch, and highly vascular, the structure of which appears eminently calculated to facilitate the action of the air upon the nutritious fluid. (*b, c, fig.* 421).

Fig. 421.



In the Amphipoda another step appears to be taken in the elaboration of the respiratory apparatus. Not only does the function of respiration tend to become centred in certain appendages, whose structure is modified for this end, but this localization, if the term may be allowed, becomes more complete; for the two appendicular portions of the thoracic extremities no longer concur indistinctly and

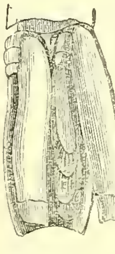
Fig. 422.



vicariously in the performance of the function; the palp (*b, fig.* 422) has other uses apportioned to it, and the flabellum (*c*) alone plays the part of the branchiæ. These appendages, in other respects, do not present any thing peculiar in their conformation; they appear like a vesicular or foliaceous expansion, of an extremely soft texture, which is attached to the inner edge of the base of the thoracic extremities; their dimensions generally increase from before backwards, and the last pair of thoracic extremities is not furnished with any: their total number varies from eight to twelve. These organs, suspended under the thorax, float in the ambient fluid, and the water in contact with their surface is incessantly renovated by means of the motions performed by the abdominal extremities of the animal, motions which occasion a rapid current from behind forwards along the ventral aspect of the body.

In the Lœmodipoda, the parts which perform the office of branchiæ are vesicular bodies formed by the flabelliform appendage of a certain number of the pairs of thoracic extremities. In the Isopoda, finally, the locomotory extremities no longer serve for respiration, the function being committed to the five first pairs of abdominal extremities which are entirely devoted to it and cease to have any other uses. These extremities, which are designated under the name of *false branchial limbs*, consist of a cylindrical articulation, supporting two foliaceous, soft membranous laminæ, vascular in a greater or less degree; frequently, too, we perceive on their inner side a small appendage, which may be regarded as analogous to the femur or stem of the other extremities, whilst the two laminæ, of which mention has just been made, appear to represent the palp and the flabellum. In the greater number of Isopoda these organs are completely exterior, but in several (such as the Idotea) the last ring

Fig. 423. *Fig.* 424.



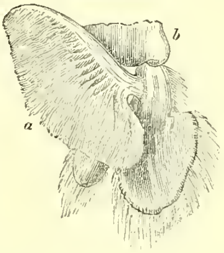
Respiratory apparatus of the Idotea.

of the abdomen supplies them with a cavity, the entrance to which is closed by valves which constitute the two appendages of the same ring.

The Stomapoda which have already supplied us with an instance of the absence of determinate organs of respiration, also exhibit something analogous to the transition state of this apparatus during the second period of the embryonic life of the Decapod. In the genus Cynthia the branchiæ are represented by a small membranous cylinder, attached by its middle to a peduncle, itself implanted upon the extremity of the basilar articulation of the five first pairs of abdominal extremities.

The third type of the respiratory apparatus specified above, is presented to us by other Stomapods, known under the names of Squillæ and Thysanopodæ. In these creatures, in fact, we discover branchiæ properly so called, the structure of which is greatly complicated, more so even than in the Crustaceans at the very head of the series; still the respiratory apparatus as a whole is much less complete, for they are not included in a cavity, and float freely in the water which bathes the entire surface of the body of the animal. In the Squillæ (*fig.*425) the branchiæ are attached to the basilar joint of the first five pairs of abdominal extremi-

Fig. 425.



One of the branchiæ of the Squilla. a, branchia fixed to the abdominal extremity (b).

ties, and each consists of a long cylindrical tube, upon one of the sides of which proceeds a series of small tubes disposed parallel to one another like the pipes of an organ and supporting in their turn a series of long cylindrical and very numerous tubes.* In the Thysanopoda the branchiæ also resemble plumes, but instead of being situated on the abdomen, they are attached to the thoracic extremities.†

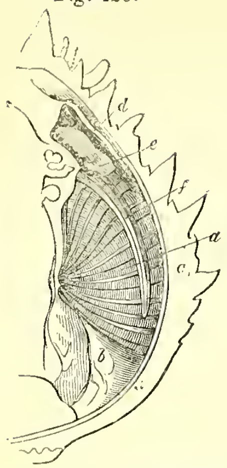
Finally, the last or highest term of development which we have mentioned in the River-crab, is also presented to us by the entire order of Decapod Crustaceans. Not only is the function of respiration thrown upon particular organs, created expressly for this purpose, in the whole of these animals, but further, the organs themselves are lodged and protected within especial cavities, and the renewal of the water necessary to their functions is secured by the action of distinct appendages belonging more particularly to the masticatory and locomotory apparatuses.

Let us now take a survey of the branchial cavity. It occupies (*fig.* 426) the lateral part of the thorax, and extends between the vault of the flancs and the lateral portion of the carapace, from the base of the extremities all the way towards the dorsal aspect of the animal. As we have already said, it is formed by an internal fold of the common tegumentary membrane, which, after having formed the vault of the flancs, re-descends towards the base of the extremities to become continuous with the carapace. The internal and inferior wall of this cavity is consequently formed by the vault of the flancs itself, and its external and superior wall by a membranous septum, which in the greater part of its extent is for the most part connected with the corresponding portion of

* Cuvier, Leçons d'Anat. comp. t. iv.

† Mém. sur une disposition particulière de l'appareil branchial chez quelques Crustacés, par Milne Edwards, Ann. des Sciences Nat. tom. xix.

Fig. 426.



Branchial cavity of the Maja Squinado laid open.

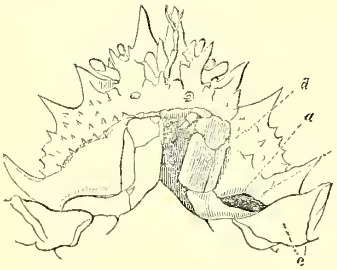
a, branchiæ; *b,* vault of the flancs; *c,* carapace; *d,* efferent duct; *e,* valve.

the carapace. This last part of the walls of the branchial cavity presents an epidermic layer of extreme thinness, but covering a thick and shaggy membrane, the texture of which is found to vary, as we shall see by-and-by.

The cavity thus formed communicates externally by two passages, the one destined for the entrance, the other for the exit of the water necessary to respiration. The disposition of the efferent opening varies but little; that of the afferent orifice, on the contrary, presents great varieties in the different groups of which the class of Decapods is composed.

The efferent orifice always occupies the anterior extremity of the branchial cavity, and is continuous with a canal (*d, fig.* 426 and *f, fig.* 428) the parietes of which are formed superiorly by the epimeral pieces of the last cephalic rings, and inferiorly by the pterygostomian portions of the carapace (*b, fig.* 427).

Fig. 427.

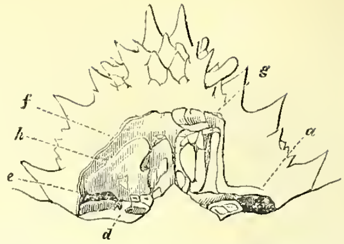


Head of the Maja Squinado.

a, afferent opening of the branchial cavity; *b,* carapace; *c,* anterior extremities; *d,* posterior maxillipedes.

This canal runs forwards, passes to the outside of the oral apparatus, and terminates in front of the mouth (*g, fig.* 428). In its interior there is a large valve, which is falling and rising continually, as if it moved upon a pivot, and which in this way occasions a rapid current

Fig. 428.



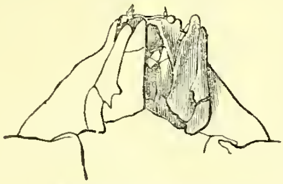
The same parts, the posterior maxillipedes and a portion of the carapace having been removed.

a, afferent opening; *d,* portion of the posterior maxillipedes; *e,* commencement of the efferent canal (*f*) *g,* the termination of the efferent canal; *h,* the valve.

from behind forwards in the water with which the cavity is filled. This valvular apparatus is neither more nor less than the flabelliform appendage of the second pair of maxillipedes which acquire dimensions in relation with the importance of the new function they have here to perform (*h, fig.* 428).

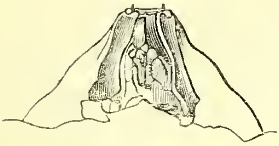
In the long-tailed Decapoda, and in the greater number of Anomoura of the same family, the respiratory cavity is open along the whole extent of its inferior edge; the carapace is not applied accurately to the lower margin of the vault of the flanc, and it is by the empty space thus left above the base of all the extremities that the water makes its way to the branchiæ. In the Brachyura the afferent orifice of the branchial cavity is more circumscribed, but varies in a still greater degree. In nearly all the Crustacea it exists almost immediately in front of the base of the first pair of ambulatory extremities, and consists of a kind of cleft, of considerable breadth, which in this place occurs between the edge of the carapace and the thorax (*a, fig.* 427), and which is occupied by a prolongation of the basilar joint of the external maxillary limb (*d*), disposed in such a manner as to close it completely or to open it at the desire of the animal. In the genus Dorippus a slight variety in the disposition of this opening is observed; here at first view it appears to be pierced directly in the pterygostomian portion of the carapace; but it is in reality formed by an empty space left between the edge of the dorsal shield and the base of the external maxillary limb; only here, this space, instead of presenting itself immediately in front of the base of the anterior extremities, is separated from this by a prolongation of the carapace. In the genus Ranina the carapace is joined to the thorax above the whole of these limbs, so as to leave no opening in this situation for the passage of the water, and it is at the origin of the abdomen that the afferent opening of the branchial cavity occurs. Lastly, in the Leucosia, this cavity is in like manner completely closed above the base of the extremities, and it is by a conduit parallel to the efferent canal, and opening outwardly likewise in front of the mouth, that the water reaches the interior of the branchial cavity.

Fig. 429.



Mouth of the Leucosia.

Fig. 430.



The same, without the external or posterior maxillipedes.

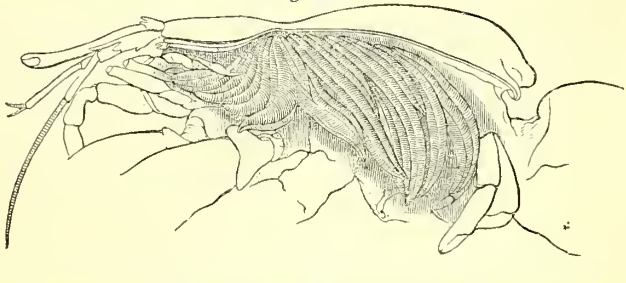
The branchiæ contained in the two cavities, one on either side, whose conformation we have now described, are disposed along the vaults of the flancs. They are shaped like a quadrangular pyramid, the base being fixed by means of a peduncle to the inferior part of this vault or to the membrane which extends from its inferior edge to the basilar articulation of the corresponding limb; some of them are even inserted into this articulation. Each of these organs consists of two large longitudinal vessels situated on the opposite edges of a transverse septum, which extends from the base to the apex of the branchia, and presents on each side a great number of lamellar or cylindrical prolongations. Of these two principal vessels the external is the afferent one, of which mention has already been made in treating of the circulation and its organs; the internal again is the efferent vessel; the capillaries by which these two communicate run in the substance of the branchial lamellæ, situated on either side of the median septum.

In the whole of the Decapoda brachyura and anomoura, and in the greater number of the macroura, the folds of the tegumentary membrane which constitutes each branchia, are in the form of very thin lamellæ, directed perpendicularly to the axis of the pyramid, aud lying one over another like the leaves of a book. But in Crawfish, the Lobster, the Nethrops, the Palinuri, the Scyllari, and the Gebiæ, these lamellæ are replaced by a multitude of small cylinders, attached by their base, and closely packed side by side, like the bristles of a brush.

The number of branchial pyramids varies greatly, especially in the Macroura; at the most it is twenty-two, as is the case in the Astacus and the most nearly allied species; in other macroura the number is eighteen, as in the Palinuri, Scyllari, Peneæ; fifteen, as in the Gebiæ; twelve, as in the Pandalus; ten, as in the Calianassæ; eight, as in the Palemons; and even seven only, as in the Crangons, Hippoliti, Sergestes, &c. In the Anomoura the number also varies very much. In the Brachyura we can almost always reckon nine branchiæ on each side of the body; two of this number, however, being merely rudimentary; sometimes two or one of these last is entirely wanting; and there are even species in which the branchia, which usually occupies the antipenultimate ring of the thorax, is missing.

The mode in which these organs are placed varies in a like degree: in the Brachyura (*fig.* 426) the whole, with the exception of two rudimentary branchiæ, are arranged along one and the same line, and rest parallel to one another upon the vault of the flancs; the two last rings of the thorax never support any, and of the two rings which correspond to the second and third pairs of extremities, each presents a single pyramid attached to a hole pierced in the epimeral piece near to its inferior edge (*fig.*384). The five branchiæ, situated in front of these, are attached above the edge of the vault of the flancs, and with the exception of the first are connected two and two upon common peduncles. Lastly, the two rudimentary branchiæ which complete the series anteriorly,

Fig. 431.



are arranged under the base of the preceding, and attached to the basilar articulation of the second and third pairs of maxillary extremities. In the Anomoura and the Macroura, the branchiæ are often found arranged in several ranks, and generally occur on the two last thoracic segments, as well as upon those that precede these (*fig.* 431).

In the greater number of the Decapoda the flabelliform appendages of the maxillary or of the ambulatory extremities penetrate into the respiratory cavity, and by their motions sweep, as it were, or stroke the surface of the branchiæ. Some anatomists have even imagined that it was by their action that the water necessary to respiration was renewed in the interior of the branchial cavities;* but this is a mistake; these appen-

* Cuvier, Leçons, t. iv. p. 432.

dages have little or no influence upon the current which is continually traversing the respiratory antrum, and which is produced by the motions of the great valvular lamina, already described as belonging to the second pair of the maxillipedes, and situated in the efferent respiratory canal.

The very secondary part which the flabelliform appendages of the thoracic extremities play in the interior of the respiratory cavities, is of itself a sure indication of the indeterminateness of their numbers and relations to the branchial pyramids. Thus whilst in the Lobster and the nearly allied genera, these appendages, to the number of five on either side, belong to the four first pairs of ambulatory extremities and to the third of the maxillary pairs, and run from below upwards between the branchial fasciculi, we only find three pairs in the Brachyura, belonging exclusively to the maxillary extremities, and penetrating into the branchial cavities horizontally, two on the outer surface of the branchiæ and one between the inner surface of these organs and the flancs.

We said in beginning this article that the Crustacea, by their general conformation, were evidently adapted to a purely aquatic life; this proposition must only be understood as generally applicable to the class, because there are genera which form exceptions to it, in regard to which we have still a few words to add.

The Telphusiæ and some other families of Crustaceans have the power of emerging from the water, and of entering it again after a longer or shorter stay upon dry land. But this fact is to be explained by the smallness of the two openings by which each of the branchial cavities communicates with the exterior, by which means a very small amount of evaporation only takes place from them. The whole of the Crab tribe have, in a greater or less degree, the faculty of the particular species mentioned, provided the air by which they are surrounded is saturated with moisture; because if they die asphyxiated when brought into the air under ordinary circumstances, it is principally because their branchiæ having become dry are thereby unfitted to accomplish their functions.

But there are other species which are remarkable for the faculty they possess not only of living habitually out of water, but because they are infallibly drowned by being kept long immersed in that fluid—these are the Gecarcini or land-crabs. Many hypotheses were broached to afford an explanation of this phenomenon, when a careful study of the different forms under which the organs of respiration present themselves in these different genera, led us to discover in the membrane which lines the walls of the respiratory cavities, modifications analogous to those which are observed among fishes of the family of the Acanthopterygia pharyngeæ labyrinthiformes, &c. Sometimes we found folds and lacunæ capable of serving as reservoirs of a certain quantity of water; sometimes, as in the Birgus, a spongy membrane equally well calculated to store up the fluid necessary to keep the organs of respiration in the state of humidity essentially necessary to enable them to perform their functions. It is well known, too, that the Land-crabs of which we are now speaking, never remove far from damp situations. Some naturalists are of opinion that the tegumentary membrane with which the branchial cavity is invested, is also the seat of active respiration; M. Geoffroy St. Hilaire even goes so far as to regard the growths with which the surface of this membrane is covered in the Birgus, as constituting a true lung.

It would appear, consequently, that it is owing to the activity of the function of aerial respiration in the Gecarcini, that these animals are drowned when plunged under water, although they be provided with branchiæ; and it is owing to these organs being kept in a suitable state of humidity that these creatures owe, at least in part, their faculty of breathing air.

We have said above that the principal cause of the death of our ordinary Crustaceans exposed to the air is the drying up of their branchiæ; but this is not the sole cause of the asphyxia they suffer; it would seem that the collapse of the branchial lamellæ which takes place when these organs are not supported by the water, and the greatly diminished extent of surface thereby exposed to the oxygenated fluid, contributes mainly to prevent aerial respiration from proving adequate to maintain life among the common aquatic Crustacea.

With regard to the modifications presented by the respiratory organs of the Onisci, which like the Gecarcini live far from water, nothing certain is yet known. The opinion that the abdominal false limbs, which serve as respiratory organs among the Isopoda in general, are here vesicular, and perform the office of lungs internally, whilst their external surface acts in the manner of gills, still requires to be confirmed.

§ 6. *Of Generation.*

Sexual organs are readily demonstrated in the whole class of Crustaceans, but those of the two sexes never exist in the same individual. The doubt which at one time prevailed in regard to this fact, and which mainly arose from no other than females of certain species having ever been taken, is at once put an end to by the circumstance of the considerable dissimilarity in their external form, which occurs between the males and females of these species; this dissimilarity indeed is, in some instances, so great that naturalists were led into the error of regarding the male and female of the same creature not only as belonging to different species, but even to different genera. Oviparous reproduction is also a constant character of the class.

Generally speaking, the reproductive apparatus, whether in the male or in the female, is perfectly distinct, especially at the period when the organs composing it are in a state of activity; and one of the most remarkable facts which the careful study of this part of the structure of the class has afforded, is their complete state of doubleness; on either side of the body we find an organ perfectly distinct, and often wholly independent of its fellow; to such an extent, indeed, is this carried, that among the facts with which modern science has been enriched in regard to the structure of the Crustacea, one by no means the least interesting is that in which an animal of this class was actually found presenting in either half of its body a different sex, each apparatus complete in every one of its conditions, and even with the whole of its modifications.*

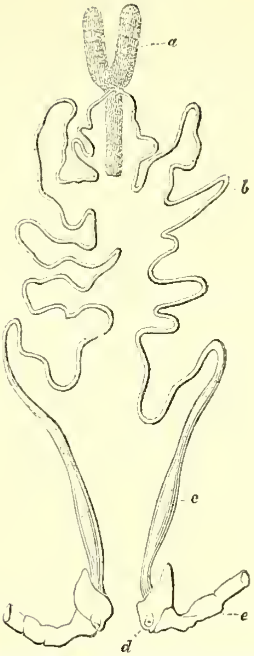
Another fact, not less striking, is that of the analogy which exists, at least among the more perfect Crustaceans, between the male and the female reproductive organ This similarity is so great that the simple inspection of the organ is not alone sufficient to inform us always of its true nature, which in some instances can only be ascertained by the most careful examination.

The male apparatus consists essentially of an organ the secreting instrument of the fecundating fluid, and of an excretory canal variously modified. These two parts are contained within the thorax along with nearly the whole mass of other viscera, and never extend lower down than the last ring of this region of the body. They are not always very distinct from one another, and it frequently happens that the testis and the excretory canal are confounded inextricably under the form of a single tube, nearly identical in its structure from beginning to end. The length of this canal is occasionally very great and variously convoluted and contorted, so that its relations with the other thoracic viscera become excessively multiplied. This peculiarity we observe very well in the Maja and the Cancer pagurus (see *fig.* 418). The canal, which throughout is single, is capillary at its commencement, but increases gradually in its dimensions to its termination.

In the Astacus fluviatilis, on the contrary, the two portions of the male reproductive apparatus are perfectly distinct, and severally completely developed. The testis (*a*, *fig.* 432) consists of capillary secerning vessels, which are readily demonstrable, and presents three lobes, two of which lie forwards upon the sides of the stomach, and one backwards underneath the heart. From these three lobes two excretory canals (*b*) take their origin. In the Edriophthalmia the male organ is composed of two or three elongated vesicles, which terminate in a common excretory canal.

It is in the Cancer pagurus perhaps that the male organ of generation is most highly developed. It occupies of itself a large portion of the thorax (*fig.* 418). The testis presents the appearance of a kind of grape cluster, formed of four principal lobes, which, studied minutely, are found to be made up of an infinity of extremely delicate vermicular canals, contorted so as to form great numbers of pellets. This first portion of

Fig. 432.



Male organs of the Astacus Fluviatilis.

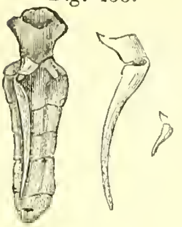
a, testis; *b*, excretory ducts; *c*, terminal portion of these ducts; *d*, orifice; *e*, last pair of ambulatory legs.

the organ is situated in front of the thorax, and terminates in a primary large convoluted vessel lying on the side of the stomach; behind and in connexion with this we perceive the vas deferens, properly so called; it is a canal of considerable size, much convoluted, and of a milky white colour; it traverses the thorax, still twisting about, penetrates the cell of the last pair of ambulatory extremities, and opens outwardly on their basilar piece. This indeed is the situation in which the copulatory organs of the Crustacea generally appear. Still, in many Brachyura of the Catometopa family, the Ocypoda and Grapsus for example, the external opening of the male generative organ is found on the sternal part of the last thoracic ring; and there are even several of these animals in which the efferent caual, after having attained the external surface in the basilar articulation of the last pair of ambulatory extremities, returns inwards, and penetrates by a small groove, which conceals it until it has attained to that portion of the sternum which is hidden by the abdomen; an example of this occurs in the Gonoplax. In the ordinary state the excretory canal terminates on the edges of the opening, but at the instant of sexual intercourse the extremity of the canal undergoes a kind of erection, and by becoming folded upon itself like the finger of a glove, projects externally, so as to form a kind of penis adequate to the intromission of the fecundating fluid. This latter circumstance was long unknown to naturalists, who were

* An account of an Hermaphrodite Lobster, by Dr. Nichols, Philos. Trans. 1730, p. 290.

accustomed to look upon the members of the first and second abdominal rings as the external male instruments. These two pairs of extremities, in fact, (*fig*. 433,) are distinguished

Fig. 433.

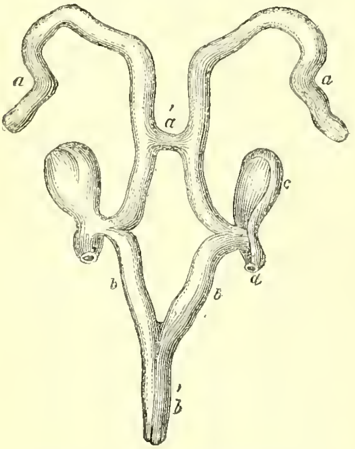


Members of the first and second abdominal rings of the Male Maja.

from the rest by their shape, which is styliform, and their structure, which is tubular, being composed of two horny laminæ convoluted one upon another, the first including the second. But direct observation has deprived them of all claim to be considered as fulfilling any office of so much consequence in the economy of the Crustacea as that of conveying the fecundating fluid from the body of the male into that of the female. At the most, they can only be regarded as organs of excitation, and which the animal may perhaps employ at the same time to guide the male into the female organ.

The female reproductive apparatus of the Crustacea, in its highest state of complication, consists of an *ovary*, an *oviduct*, and *copulatory pouches*.

Fig. 434.



Female organs of the Maja Squinado.

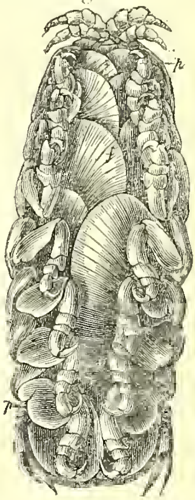
The ovaries in the Decapoda brachyura resemble four cylindrical tubes (a, b, *fig*. 434) placed longitudinally in the thorax, and divided into two symmetrical pairs, each opening into a distinct oviduct, yet communicating with one another by a transverse canal (a'), and by the intimate union of the two posterior tubes in a portion of their length (b'). The oviducts, as well as the ovaries, are of a whitish colour; they are short, and become united in their course to a kind of sac (c), the neck of which extends to the exterior of the animal's body (d); there is one of these on each side, and they are known by the name of the *copulatory pouches*. It is into these reservoirs that the male pours the fecundating fluid, which is here stored up and applied to the ova as they pass in succession along and out of the oviducts. These after a course, which is never long, terminate at the vulvæ, openings formed in the sternal pieces of the segment which supports the third pair of ambulatory extremities.

The Anomoura and Macroura have no copulatory pouches, and their vulvæ are situated on the basilar joint of the ambulatory extremities of the third pair. The mode in which fecundation is accomplished in these genera is consequently much less apparent than in the Brachyura. Many writers are of opinion that this operation takes place in the interior of the ovaries, a process that appears by no means feasible on account of the inequality of development of the ova, which is such, that the last of them are not in being even long after the first have been expelled. It would perhaps be more correct to suppose that fecundation does not take place till after the ova are laid, which we know to be the case among the Batrachia and the greater number of Fishes.

The female Crustacean does not abandon her eggs after their extrusion. Those of the Decapods preserve them under their abdomen by means of the abdominal extremities modified in their structure (*fig*. 390 and 435); the Edriophthalmia, again, keep them under their thorax by means of the flabelliform appendages of the extremities belonging to this region (*fig*. 436); whilst the inferior genera, such as the Entomostraca, &c. have suspended to the external orifices either horny tubes or a

Fig. 435.

Fig. 436.



Ventral aspect of the female Cymothoa.

p, legs; f, flabelliform appendages which unite so as to form a cavity destined to contain the ova.

pair of membranous sacs which contain and transport them from place to place. These varieties in the accessory organs of generation, are in many cases sufficient to distinguish the sexes: thus, among the Decapoda brachyura, the females are known at a glance by their wider abdomen, which is sometimes of such dimensions as to cover almost the whole sternum. Sometimes these sexual differences extend to the antennæ and to various other organs; sometimes it even influences the size, and occasionally, as we have said, the general external conformation is modified to such a degree, that the male and the female of one and the same species have been taken as types of two distinct genera. There are some species of which the females only are as yet known to naturalists.

The ovum appears to be formed in the walls of the ovary, from whence it is detached when it has attained a certain size, and falls into the cavity of the organ. We have already stated in what manner it is expelled, and in what mode fecundation is accomplished in its passage through the oviducts, or after its extrusion. The distinguished German naturalist, Rathke, has given particular attention to the divers phases of the evolution of the egg of the Astacus fluviatilis, as well before as after its escape from the ovary and oviduct; and we believe we cannot conclude this article more satisfactorily than by presenting our readers with a simple and brief analysis of his work.*

The first and earliest form under which the ovum meets the eye in the ovary is that of a transparent vesicle, its walls of extreme tenuity, and filled with a watery fluid. This is the *vesicle of Purkinje*. By-and-by there is another membranous and very thin envelope formed all round this vesicle, and in the minute interval that separates the two coverings there is a second fluid deposited, transparent like the other at first, but soon becoming opaque, whitish, and viscid; this is the *vitellus* or *yolk*. As this increases in size, the vesicle of Purkinje, which still preserves its first dimensions, quits the centre, and goes to be attached to the circumference, which, at last, it almost touches at one point. During this time the vitellus or yolk is continually declining in transparency, on account of the formation of an infinity of globules, which, at length, transform it into a viscid mass of a deep brown colour.

During the last stage of its continuance in the ovary the vesicle of Purkinje disappears, and the first rudiments of the germ are discovered. This series of changes might induce the belief that the germ is neither more nor less than the liquid of the vesicle shed upon the surface of the vitellus. Its form at first resembles that of a slight whitish cloud, which, by slow degrees, changes into an opaque white spot, well defined, and covering nearly the sixth part of the entire surface.

The egg is in the above state at the time it is received into the oviducts. These canals secrete an albuminous fluid, which surrounds the vitellus and its envelope, and which itself becomes covered with a membranous involucrum, called the *chorion* or dermoid envelope of the ovum. Another membrane still is thrown around the last, to serve as the means of attaching the ovum to the false abdominal extremities of the mother.

When the process of incubation begins, the surface of the yolk is first seen to become covered with star-like or serrated spots whitish in the first instance, and then white, which by-and-bye disappear entirely. The germ at the same time is extended uniformly over the whole surface of the yolk; but again it seems to collect towards a point under the form of a white spot, which is the *blastoderma*. This spot, after undergoing certain variations in its form and dimensions, ends by becoming elliptical with a slight furrow in its middle, shaped like a horse-shoe. This furrow soon extends; its extremities meet, and its centre becomes depressed, so as to assume the appearance of a sacculus of some depth. The blastoderma enlarges at the same time, and presents the appearance of a cordiform spot. It is at the bottom of the sacculus but just mentioned, and in the nearest point of the blastoderma, that the first rudiments of organs make their appearance.

It is now that the orifice of the sacculus begins to enlarge; the edges separate; its bottom rises, so as at length to become prominent, and a small nipple-like elevation appears upon it, hidden in some measure by the edge of the sac, which turns out to be the rudiments of the posterior portion of the body. At the same epoch there are formed anteriorly, on either side of the median line, two pairs of small strap-like bodies, which are by-and-bye discovered to have been the rudiments of the antennæ, and another pair, which are the earliest vestiges of mandibles. Between the two anterior antennæ an azygous point presents itself, which is the rudiment of the labrum, and which, by the progressive development of the neighbouring parts, shifts by slow degrees to its final position between the second pair of antennæ.

By slow degrees the blastoderma, the peripheral portion of which is much thinner and more transparent than the middle portion, is seen to extend on the surface of the vitellus, and at length to envelope it completely. During this time the three pairs of spots which represent the antennæ and the mandibles are growing larger, their edges becoming distinctly defined, and their extremities are receding from the surface of the blastoderma, under the form of a little cylinder, the end of which before long divides into two. After the antennæ have been seen, the peduncles of the eyes make their appearance, and detach themselves by degrees from the blastoderma, as the preceding appendages had done. The nipple-like projection which we have seen formed at the bottom of the small blastodermic sac enlarges at the same time, and assumes the form of an

* Untersuchungen ueber die Bildung und Entwickelung des Flusskrebses, fol. Leipz. 1829.

elongated lamina, the free end of which is turned forwards, and before long advances nearly to the labrum.

In the space included between the mandibles and the fold formed by the abdominal lamina of the embryo, of which we have just spoken, we now perceive the rudiments of two pairs of jaws and of the first pair of maxillary extremities, then of the second pair of these latter organs, and soon afterwards of the third pair. These appendages appear in the same manner as the antennæ, and in proportion as they are evolved, the fold that marks the origin of the caudal lamina of the embryo recedes from the anterior part of the body; by little and little the basilar portion of the lamina becomes straightened, so as to gain the same plane as the remainder of the blastoderma, whilst its terminal portion continues bent underneath against the former. The five pairs of ambulatory extremities make their appearance successively in the same manner as the antennæ and the oral appendages; the same may be said with regard to the abdominal extremities; and whilst this formation is going on, the annular divisions of the abdominal portion of the body are observed to be evolved. The carapace at length begins to be formed in the manner already indicated, and the extremities, as they sprout, alter their shapes, and become more and more unlike one another, as they approach the term of their embryotic development.

The alimentary canal begins to be formed by its two opposite extremities. The earliest traces of the oral aperture are perceived nearly at the same time as the labrum, under the form of a small cavity, which becomes continually deeper and deeper. Some short time afterwards, and before the appearance of the jaws, we distinguish towards the summit of the abdominal tubercle, a slight depression which grows rapidly deeper in order to form the anus. About the same period a very delicate and gelatinous-looking membrane begins to be formed between the inner aspect of the middle portion of the blastoderma and the vitellus; this increases rapidly, and sends prolongations towards the mouth and anus, which soon become hollowed out into a cavity, and are finally converted into two small perpendicular canals. The one of these canals terminating at the mouth is the commencement of the œsophagus and stomach; the other, with which the anus is soon found to be in connexion, is the rudiment of the intestine. The rest of the membrane in question is observed to extend rapidly and at length completely to envelope the vitellus. At this epoch of the development of the embryo, the sac thus formed covers the blastoderma, incloses the yolk, and towards its lower part presents two funnel-like portions by which it is made to communicate with the gastric and intestinal portions of the digestive canal, the formation of which we have just had occasion to speak of. These two portions of the digestive canal as they increase in size approach one another; the rest of the sac folds inwards upon itself, and diminishes more and more in size until it disappears entirely, and the stomach and intestine form one perfectly continuous tube. At the point where the intestine is connected with the sac inclosing the yolk, two small thickenings are seen, which by-and-by acquire the form of appendages and become covered with little warty-looking enlargements; this is the liver beginning to be formed. The enlargements of which we have spoken constitute its lobuli, and these slowly divide into a multitude of long slender vessels.

The heart begins to be developed about the same time as the intestinal canal. It makes its appearance towards the dorsal part of the body, a short way above the commencement of the abdomen, and shows itself at first under the guise of a small pyriform cavity hollowed out of a membrane supplied by an inner lamina of the blastoderma. The arteries begin to show themselves towards the same period in the substance of this same blastodermic lamina, and in the beginning present neither ramifications nor any communication with the heart.

We have already spoken of the development of the apparatus of respiration and of that of the nervous system at such length as to render it unnecessary to enter farther upon these parts of the subject here.

The greater number of the Crustacea do not escape from the membranes of the egg until they have attained such a perfect state of development, that they possess the whole of the organs they will ever exhibit, and have attained a form which differs but little from that which is to distinguish them when arrived at maturity or become adult. The case, however, is different as regards some of these animals; these are born in some sort prematurely, and only attain their distinctive formation after their exit from the egg. The changes which they undergo between the term of their birth and that of their perfect growth are sometimes so great that they are every way deserving of the name of metamorphoses.

These changes, whatever their amount, may depend on the following circumstances:—1. the continuation of the normal work of development, which has not been completed in the ovum; 2. the unequal growth of different parts of the body; and, 3. the atrophy and complete ultimate disappearance of certain parts.

It is among the lower Crustaceans that this kind of premature birth takes place most frequently: thus the sugient Crustaceans and the Entomostraca quit the membranes of the ovum at a stage of development which corresponds with one of the earlier of those under which the Decapoda present themselves to our notice; they are all of an oval figure, and only appear provided with a very limited number of styliform extremities. The common Cyclops, for instance, does not show the posterior part of the body at the time of its exclusion from the ovum, although this subsequently forms an elongated tail; it is nearly spherical at first, and is provided with no more than two antennæ and four extremely short feet. It continues in this state till the fourteenth day, when a small projection makes its appearance from the hinder part of the body; on the twenty-second day it acquires a third pair of extremities, and on the twenty-eighth day it changes the tegumentary covering of its body.* Several Edriophthalmians are also born before they have acquired the whole of their extremities; but we know of no instance of the appearance of one or more pairs of extremities after exclusion from the ovum among the superior Crustaceans.

The changes of form which take place in parts already existing, and which depend on the unequal rates of increase with which the different parts of the animal approach their final state of development, are often very considerable, and commonly tend to occasion peculiarities of conformation in the adult, which distinguish it from allied species, and imprint upon it the character proper to the tribe, genus, species, and even sex to which it belongs. These implicate one part in one, another in another; here it is the thorax which grows more rapidly than the abdomen and greatly preponderates; there it is the abdomen which, smaller at first than the thorax, increases in dimensions, and finally exceeds it in size: in other instances, again, the phenomenon of extraordinary growth is displayed in certain extremities, or even in certain articulations of these extremities, which follow differences in the proportions of the body and in the forms of its different parts. These differences contribute in general to increase the dissimilarity which already exists between the different segments of the body, and may therefore be regarded as a sequence in the general tendency of these animals to become more complicated in their structure in proportion as they rise in the series to which they belong, or in the course they have to run in order to attain their perfect state.

To conclude: the modifications depending on the atrophy and the disappearance of certain parts with which the embryo is provided, tend also to individualize in a greater and greater degree the animals which experience them. As an instance of this phenomenon we may quote the disappearance of the eyes in certain Haustellate and certain Edriophthalmian Crustaceans, and that of the greater number of the extremities in a great many of the Lerneæ. The Dromiæ, among the Decapod anomoura, have also presented us with an instance of changes, analogous in their nature and in their consequences; for among the young animals the abdomen terminates in a caudal, fan-shaped fin, as among all the Macroura and a great many of the Anomoura; but with the advance of age, the lateral laminæ of this organ disappear, and the abdomen then terminates very nearly as it does in the Brachyura.

It is among the Crustacea which are born in the most imperfect state, and which consequently have the greatest number of changes to undergo, that the young animals bear the greatest resemblance to one another. The anomalies of conformation encountered among these Crustacea do not in general show themselves till the latter periods of their growth.

The length of this article (already, perhaps, too great) does not allow of our pausing longer on this subject, and we shall only add that the evolution of the Crustacea is one of the points in the history of these animals which appears to promise the most interesting and important series of facts to whoever will devote himself to the comparative and extended investigation of the subject.*

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(H. Milne Edwards.)

CYST. *Kystus*, (κυστις, bladder). Certain membranous investments, of various forms, though commonly spheroidal, being shut sacs, and developed in the midst of other tissues, have obtained the name of *cysts*.

Up to the present moment the study of cysts is so little advanced that we can scarcely discover any researches which would appear to be founded upon the observation of nature. Whilst so much attention has been devoted to the investigation of many departments of pathological anatomy, it is difficult to understand why this very interesting subject has been comparatively neglected. The singularity of the circumstance is not lessened by the reflection that the rules of therapeutics ought to vary with the character of these sacs, and that, consequently, the anatomical study is of first-rate importance in enabling us to proceed rationally in the treatment of these extraordinary products of the animal economy.

In describing these organs, two modes have commonly been employed; the one, to consider them with reference to the product they contain; the other, with reference to their proper structure. It is not our intention to adopt either of these methods of considering the subject, and for the following reasons:—it is demonstrable that cysts which are identical in texture frequently envelope totally different products, and also that the products and the cysts are susceptible of transformation to an almost indefinite extent; and as neither method

* *Jurine*, Histoire des Monocles.

* See on this subject the observations of Rathke already quoted; those of Thompson, "the Metamorphoses of the Crustacea;" our own "Recherches sur les changemens de forme que les Crustacés subissent dans le jeune age." (Annales des Sciences Naturelles, tom. xxx. and 2ne serie, tom. iii.) and the inquiries of Nordmann in his Mikrographische Beiträge, &c. 2tes Heft.

affords us any facility in distinguishing one kind of cyst from another, we hold them alike inadequate to lead to correct views of the subject. The plan which we propose to follow may not afford any increased facility in diagnosis, but it is, we apprehend, founded upon a more stable basis than either of those to which allusion has been made. We mean to consider cysts with reference to the mode of their developement; and although we do not pretend that this arrangement will afford much greater facility than at present exists for the diagnosis of the species, yet it appears to us to be the most natural classification which, in the present state of our knowledge, we are enabled to offer. A considerable assistance in the diagnosis of these organs may be obtained from the adoption of the following principles, which, though not unerring in their application, will afford a very near approximation to the truth, in the majority of cases. Those cysts which are external, subcutaneous, and exactly globular, with a thinning of the dermis, which seems to adhere to their surface, commonly contain sebaceous matter of a whitish colour, friable and semi-concrete; those which occupy muscular interstices in the neck, the back, or the extremities, have, commonly, thin parietes, are cellulous, of irregular form, and contain either serosity or albuminous pus, in which are seen floating opaque flocculent particles; those which surround articulations and tendinous sheaths—true appendices of synovial tissues—are strengthened externally by fibrous laminæ, lined by a serous tissue, and contain a more or less pure synovial fluid; those which are developed under the anterior annular ligament of the carpus sometimes contain small whitish bodies, in appearance not unlike a grain of boiled rice; those which occupy internal cavities, attaching particularly to the liver, usually contain hydatids, and to the ovary contain a variety of products, sometimes serous, sometimes sanguinolent, sometimes gelatinous.

Until a better method of diagnosis is presented, the situation of the organ will therefore facilitate to some extent the knowledge of its contents. No one, however, will rest satisfied with this means, nor underrate the necessity of pursuing the investigation of these organs, until we are in a condition to state with more certainty the elements for their diagnosis.

We believe that all cysts may be ranged under one of the three following categories. A cyst may be a simple enlargement, or exaggerated developement, or other modification of an existing organ. It may be produced by the irritation excited by the presence of a foreign body, whether that body be a shot or other substance introduced from without, or a tubercle or other abnormal product developed within the body. It may be a new formation not before existing in the economy, and preexistent to the matter which it may be afterwards found to contain.

The last of these categories has not usually constituted an element in the consideration of the mode of formation of cysts, and the subject has in this way been divested of the difficulties which it must otherwise present. Many accurate observers have expressed a belief that cysts were a consequence of the irritation occasioned by a foreign body; in this way a large proportion of these organs must be entirely excluded from consideration, or must be treated of under the term acephalocyst. Another class of observers, admitting the existence of the foregoing, have added another variety:—they have assumed that the parietes of an alveolus of cellular tissue are attacked by some "*morbid affection*" by which all communication with the adjoining cells is cut off; that the parietes of this alveolus, under the influence of irritation, acquire the power of secreting a product entirely different from that which they furnish in their natural condition; that the accumulation of this morbid product causes a progressive distention of this small cavity, and a thickening of the cellular laminæ in the midst of which the tumour is developed: in other words, that the tumour so produced acts in the same manner as a shot or other body introduced from without. In the opinion that all cysts are so produced, they are fortified by the belief that, by the process of maceration, of inflammation, or of suppuration, it is possible to reduce the parietes of these organs to their "*original element, cellular tissue.*" Such was the opinion of Morgagni, Haller, Louis. The opinion propagated by Bichat, that a certain uniformity in structure obtains in all cysts, that they are all analogous to serous membranes, will, it is believed, be found incorrect; there are many cysts which in structure and function are essentially different from serous tissues, for instance, some are fibrous, cartilaginous, osseous, others are cutaneous, others covered with hair.

Our *first class* contains the greater number of those subcutaneous tumours which are so commonly seen under the integuments of the cranium, the face, and some other parts of the body, and which contain meliceric, atheromatous, steatomatous, or other matter. It has been over and over again demonstrated that those follicles which open upon the surface of the body may have their aperture obliterated: the secretion from the internal surface of the organ may still proceed, and they occasionally attain a considerable volume; in this way "*steatomatous*" tumours are produced. The matter contained in these tumours has been analysed by Thenard, who obtained the following results.

One hundred parts submitted to desiccation were reduced to forty, which treated by alcohol were, in fact, dissolved: the alcohol in cooling deposited a fatty matter, which was easily melted and was similar to adipocire. The residuum, which formed sixteen parts, was of an albuminous nature; consequently there were twenty-four parts of adipocire. This adipocire did not crystallise like that of the biliary calculus in man; it was deposited in flakes like those of putrid animal matter dissolved in alcohol: yet, in the matter of the cyst, it was in the form of very brilliant micaceous laminæ. These cysts frequently appear very thick, but this great thickness is a consequence of their being almost constantly lined by an inorganic coat, which is sometimes susceptible of being divided into laminæ; when this coat is removed, there remains a very thin cellular membrane. If the lining membrane be irritated, the secretion as well as the membrane may be modified; and the variety of these subcutaneous tumours is thus explained.

Other cysts differently formed appear to arrange themselves most naturally in this class; of such are those which succeed to the obstruction of a salivary duct, ranula for instance; those which succeed to a fistulous canal, and are produced by the obliteration of the orifices of such canal; the mucous tissue by which the canal was previously invested becomes changed in its organization, and a serous character is acquired:—those which are occasionally produced in the lungs, by the obliteration of the canal of communication between a tubercular cavity and a bronchus; in this case also a serous membrane is developed within the cavity.

The second class.—Every foreign body, fluid or solid, formed within or derived from without the animal economy, induces in that economy an effort at expulsion. Whether the body be a shot, a bullet, or other projectile, or whether it be extravasated blood, stone in the bladder, the fœtus in extra-uterine pregnancy, acephalocysts, tubercle, or other heterologous or analogous formation; in all cases irritation or inflammation is developed, for the purpose of expelling or isolating the nocuous body. If it be in its nature irritating, it excites inflammation, and is expelled with the pus which has been secreted around it; if it have no mechanically or chemically irritating property, it may remain in the midst of the organ, sometimes passing from cell to cell, obedient always to a kind of eccentric movement; sometimes nature isolates it by organising around it a cyst which is adherent by its external surface to the surrounding tissues, but which is free and smooth internally,—furnishing a fluid by which many of these bodies may be broken down, and as soon as they are removed, the walls of the cyst become reduced into cellular tissue by absorption.

Frequent opportunities are afforded for examining these structures in the cellular tissue. When a certain quantity of a succulent fluid is accumulated in this structure, if it cease to increase, the parietes of the cavity which contains it continues to be the seat of a chronic inflammation by which the formation of a *cyst* is determined. Until the organisation of this cyst is perfected, the surrounding cellular tissue continues red and indurated; but as soon as the organ is completed, this redness and induration are commonly in progress of dissipation; in some cases, however, they remain, and then it occasionally happens that the cyst participates in the morbid action, and the interior of the cyst may have a pseudo-membrane developed on its surface. *Cysts* so developed are at their commencement soft, not very consistent, and may be easily detached from the surrounding structure. The inflamed stratum, between the cyst and the adjacent healthy tissue, gradually acquires a greater density and more power of resistance, at the same time that it becomes thinner, and contracts a more intimate union with the *proper* membrane of the cyst. When the organisation of this species of cyst is completed, the membrane is whitish, opaque, more or less thick, and as a point of comparison, denser, and thicker than a serous membrane, and it presents a surface somewhat similar to that membrane.

In making a third class, it must be obvious that we incline to the opinion of Delpech, "that certain cysts do not proceed from an accidental and mechanical modification of the cellular tissue," but that they are so many new organs, so many newly developed tissues, which do not possess either the same degree or even the same kind of vitality as the surrounding parts.

In this class we range those which contain a serous or sero-mucous fluid, which are developed in various parts of the body. Their parietes are sometimes transparent, at others opaque; upon their inner surface they usually present a kind of tomentum or velvet-like texture, sometimes it presents hair. Their external surface is sometimes free on all sides except that upon which the vascular communication obtains, sometimes they are completely adherent. They are observed free and almost floating in the cerebral cavities, in the kidney, the liver, the lungs, and in all serous cavities.

We also include in this class certain synovial cysts, which are observed around the articulations of the hand, of the foot, sometimes of the knee, and in the neighbourhood of the sheaths of tendons. Some persons have been disposed to refer the origin of these organs to a displacement of the synovial membrane which has yielded at this point; but observation has demonstrated that they are cysts with dense and fibrous external, and serous internal parietes, developed in the cellular tissue surrounding the normal synovial sac.

In the same class we place a species of cyst developed, so far as we yet know, under the anterior annular ligament of the carpal articulation,—more rarely in the vicinity of the tibio-tarsal articulation, but always around synovial sacs or tendons, and essentially constituted of small white bodies, in appearance similar to small grains of boiled rice.

Of the serous cysts, we may frequently find some very small, and, as nearly as may be, empty, the membrane being puckered and plicated, and in contact with itself at points where the plicæ meet. At a certain period of their existence there is scarcely a particle of fluid accumulated in them, and of course the first exaggerated exhalation which has place will be lodged without any obstacle in the cavity, the plicæ will be effaced, and the parietes removed to a certain distance, the one from the other. It is probable that this proportion between the cyst and its contents is maintained until some irritation shall accelerate the exhalation, much as in the serous cavities of the body. This exhalation is sometimes so abundant and rapid that the parietes become irritated and inflamed, and these tunics, at first characterised by so much tenuity, may, by the pure and simple effect of their rapid development, or as a consequence of their relation with very moveable organs, or by the effect of accident, to which they are exposed, become susceptible of almost unlimited transformation.

We believe, therefore, that all the varieties composing this class owe their existence to irritation; in the synovial the irritation is specific and caused by pressure,—in the serous, we believe it to be of another kind,—in many of them it is similar to that which presides over the development of hydatids: the only difference between certain of them, those, for instance, which are so nearly isolated, having merely a vascular communication, and an hydatid, is perhaps simply, that their existence has not been sufficiently prolonged to permit with safety the rupture of this umbilical cord, if I may so term it, by which they are connected to the surrounding tissues. We must now endeavour to explain the circumstances under which these cysts are developed.

The experiments and observations of Cruveilhier shew, in the most convincing manner, that humidity, abundance, and the bad or vegetable quality of the nourishment of an animal, are unequivocal means of producing acephalocysts. If by the concurrence of these circumstances acephalocysts may be produced, it must be evident that by the agency of the same causes a modification of existing tissues,—irritation, in fact, of a specific kind, has been excited by which a state favourable to their development has been produced. Admitting then that by such means a particular kind of irritation may be set up in certain tissues, we must go further; that irritation must be sufficient to cause the exhalation of a particle of lymph, that lymph, as in the case of a pseudo-membrane, becomes organised, acquires step by step an individual existence, it will be the minimum of organisation and independent vitality, but still, when its separation is achieved, it will be a living being. Supposing this idea to be correct, it may follow that a variety of modifications of such products, more or less independent, may be in a similar manner produced.

It is certainly difficult to reconcile the mind to the idea that the process of irritation or of inflammation can, under any circumstance, excite the development of an animal possessing to a certain extent an independent existence, but this is not more difficult than to conceive that molecules of a plastic living substance may form organic membranes, and yet this is demonstrable.

This has been clearly shewn in the article ADHESION; in fact, the more we study the phenomena of organisation, the more we are impelled to admit a proper vitality in certain products of living bodies. The analogy which exists between false membranes and hydatid sacs appears to be especially calculated to elucidate this subject. But whilst the false membrane remains in vital communication with the individual, the acephalocystic false membrane is detached and enjoys an independent life; the false membrane acquires a vitality rivalling that of normal tissues.

We believe, therefore, that a cyst may be developed, which, as far as general appearances are concerned, shall be analogous to the acephalocysts, wanting, however, the one great attribute, independent existence, and having a vascular communication with the tissue upon which it is developed: are not those cysts which are often seen upon the cortical substance of the kidney, and upon other organs; of this class or character?

Dr. Hodgkin* has inferred that those cysts which are so often found on the surface of the kidneys owe their existence to the obstruction of an excretory canal; others have believed that this fact was demonstrated, because it was said that their contents had the odour of urine. Without denying this position, I may state that the smell of serum and that of limpid urine are not very dissimilar. If they were a consequence of the obstruction of an urinary duct, it is evident, from the size they sometimes attain, that secretion has proceeded after the obstruction has been developed; why then does it not go further? why do they not attain considerable magnitude?

In the earlier periods of their existence the organisation of these bodies is simple, but in their progress they may experience many modifications. Their internal and external surfaces are essentially different; the internal is usually smooth and polished like serous membranes; sometimes it is soft, flocculent, and easily detached: the external is in contact with cellular tissue, and partakes more or less of its character, but frequently it acquires a density which distinctly separates it from the surrounding tissue. There is scarcely any form of transformation which may not occur in these organs. The internal surface occasionally acquires a very complicated organisation; it may be covered with hair proceeding from follicles developed in its parietes, and it may present other anomalies. The external surface may acquire a very considerable density, and may present something like a fibrous appearance, but upon further investigation we find that it does not possess any fibre, neither does its texture offer any linear or radiated arrangement. When once organised, the tunic which constitutes the cyst enjoys all the attributes of living tissues, and is susceptible of similar morbid modifications. It may become inflamed, it may degenerate into a cartilaginous state,—may become incrusted with phosphate of lime, converted into erectile tissue,—may become scirrhous, and so on; and the exhalation or secretion may be so changed that cysts of similar origin may contain the most dissimilar products.

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(B. Phillips.)

* Med. Chir. Transact. vol. xv. part 2. p. 270.

DEATH.—(Lat. *mors;* Gr. *θάνατος;* Germ. *Tod;* Fr. *mort;* Ital. *morte.*) This word has acquired a variety of meanings, which it will be proper to enumerate, before explaining the sense to be adopted in the following article.—Death sometimes expresses the time when an organic body loses the characters which distinguished it while living; in which signification it is the opposite, not of life, but of birth, or the period when life began; this period being dated in the animal either from the time when it left its ovum or its parent, or from the very moment of conception; and in the vegetable, either from its emergence above the earth, or from the first impulse of germination. In another acceptation, Death is that altered condition of an organic body in which it is no longer the subject of certain processes which constituted its life. Thirdly, it may signify that series of changes which immediately precede the cessation of life;—in this meaning, death is the act or process of dying. Lastly, in the human subject, the word is employed to express the separation of the soul from the body. It will be our object not so much to follow out these several significations, which would lead into a very wide if not a vague discussion, as to consider the precise nature of that condition of the animal body to which the term Death in its physiological import is applicable, and to enquire by what signs that state may be known to be either impending, or actually present.

Death in its most restricted sense may be defined to be that condition which immediately succeeds the abolition of *all* those actions or properties which distinguish living from brute matter, a condition not merely negative but privative. But death is likewise applied to certain states of the organic system in the higher animals, in which the abolition of the functions is not universal. In the former sense, an animal is not dead until every vital action throughout the tissues has been extinguished; while in the latter, dissolution is considered to have taken place when the circulation and respiration have ceased, because the cessation of the others almost uniformly follows. We have here then an obvious distinction of Death into two kinds, which will be found to correspond with a very natural division of the vital actions into two classes; 1, those which transpire between the particles of which living bodies are composed (nutrition and contraction); and 2, those which occur between certain collections of organic particles, called organs, and by virtue of which these organs constitute a whole system—(respiration, circulation, innervation, &c.) The extinction of the former of these classes of functions we shall venture to designate *Molecular Death;* of the latter, *Systemic Death.**

The following truths respecting the mutual influence of these two kinds of death will be illustrated in the course of the present article: 1st, That molecular does not necessarily involve systemic death, unless the former is universal. 2dly, That when partial, as in mortification, the tendency of molecular to induce systemic death depends on the importance of the part to the whole. 3dly, That molecular death in one part can only induce the same change in another part, by means of its interference with one of the systemic functions. 4thly, That systemic death must necessarily be followed sooner or later by molecular death,—but that, 5thly, The reality of systemic death can only be proved with certainty by the occurrences pertaining to molecular death.

MOLECULAR DEATH.

Molecular life is constituted by two functions, Nutrition and Contraction, for which certain conditions are requisite. The former demands a mechanism or tissue of pores or infinitely minute tubes, the ingress and egress of fluid, and a certain quality of this fluid; the latter, a fibrous arrangement of particles, in most animals and in all a peculiar property called irritability or contractility. The violations of these conditions are necessarily followed by molecular death. We shall consider them in detail.

Destruction of the tissues.—It is all but a truism to assert that the function of a tissue must cease when its mechanism is broken up, though mere integrity of the mechanism is insufficient to maintain the function. The changes which ensue are as follows. The substance is no longer capable of receiving and transmitting fluid in the same manner as formerly; the fluid which it contained is either confused with the disorganized solid particles, or is altogether eliminated; the fibres are unfitted for contraction; and the nervous filaments are paralysed. In this condition the part has obviously no kind of connection with the rest of the system, by the exchange either of fluid, or of nervous influence; it is dead both absolutely and relatively. If the other organs survive its death, certain processes commence in its immediate vicinity, by means of which a mechanical as well as a vital separation is effected; while the mortified part, as it is technically called, is abandoned to the play of various chemical affinities among its particles, and between these and surrounding agents. According as these changes are less or more advanced, there is gangrene or sphacelus. It may happen however that the other parts of the frame may lose their vitality soon after the local injury; but their dissolution will depend upon the violation of other conditions than that which we are at present discussing. Thus the part disorganized may be essential

* We should have been glad to have avoided a word so incorrectly formed as *systemic,* but its use ha sbeen sanctioned by too many and too great authorities for us to venture upon the substitution of a newly-created one. The writer is indebted to his friend Dr. Prichard for the suggestion of *somatic,* which is at once correct, and sufficiently characteristic, but he has not had the courage to introduce it into the text, though supported by an authority no less eminent in philology than in general science.

to the distribution of blood throughout the system, and the other parts may die from the want of this supply, their mechanism remaining entire. Or the injury, notwithstanding that the part may not be thus functionally essential to the circulation, may exert a no less certain operation, either indirectly by an impression made upon the central organs of innervation, and reflected upon those of circulation and respiration, or immediately by an impression upon the latter. (See the remarks upon Systemic Death.) The propagation of the dissolution will depend much upon the peculiar organization of the animal; but in all cases, as we have already intimated, textural death in one part has no immediate influence in producing the same kind of death in other parts; the latter event will be found attributable to the impediment offered by the former to some important function of the whole system. The textural lesion which we have been considering may be caused either by mechanical violence, or by chemical action, such as that of corrosive substances and of heat. It is possible that solid tissue may undergo spontaneous decomposition, but we are unable to ascertain the fact, because in ultimate structure, where fluids and solids are so intimately intermixed, we have no means of distinguishing the priority of changes.

Arrest of the fluid of nutrition.—The access of this fluid is variously provided for in the different classes of animals. The capillary circulation in the higher species resembles that which suffices for the whole system in the lower species, inasmuch as the blood in the capillaries of a tissue bears the same relation to that tissue, as the water in the stomach of one of the Radiata to the whole animal. The consequences of abstracting the fluid in the one case, or of cutting off the supply of blood in the other by obstructing its vessels, will be precisely analogous. The polype will desiccate, lose its proper form, and decay; the medusa will shrivel and putrefy; while in man the tissue dies, and is decomposed, as in senile gangrene, or in the sloughing of a hæmorrhoid to which a ligature has been applied. Suppression of the action of the heart violates throughout the body the condition of vitality under discussion, and consequently all the tissues die, but the phenomena which they exhibit are not the same as in more partial obstruction of the circulation, because the chemical agencies are different, particularly that of surrounding heat. A gangrenous spot is under the influence of an atmosphere of 98° at the lowest; while the dead or dying organs of animals, which have been simultaneously deprived of their circulation, are submitted only to the temperature of the media in which they may chance to be placed. The higher this may be within certain limits, the more closely will the putrefactive changes resemble those of gangrene. It must be remembered, however, that in the latter case other chemical agents are probably presented in the fluids effused by those contiguous parts which still maintain their vitality.

Dependence upon the circulation differs in different animals. The heart of a salamander may be excised, and yet the animal will live for several hours, or even a day or two after the operation;* its possession of life being inferred from the exhibition, not merely of certain organic actions, but even of those of relation. It is plain, then, that in animals of this tribe, the brain and spinal marrow and other organs do not require so constant an intercourse with the blood as in certain other species; and while we know with tolerable certainty that they do not need it for calorific purposes, it is not improbable that their textures are less frequently repaired than those of the warm-blooded classes. Dr. Edwards concludes that life in the above instance is maintained by the organs of innervation, whose function, as we have remarked, continues unimpaired. We should regard the integrity of their action rather as a *sign* than as a *cause* of continued vitality; other signs being perceptible in the persistence of the capillary actions, for which the fluids still remaining in the tissues may be sufficient.

Retention of fluid in the tissues.—Removal of the effete fluid is provided for in the Porifera by ejects; in the Polypifera by expulsion from the central cavity and by transpiration; in the Acalephæ by anal apertures; and in vascular animals by vessels especially appropriated to the purpose, by transpiration, and by various excretions. This condition of molecular life is less easily violated than those already spoken of, because the modes of fulfilling it are more numerous. This is equally true whether we speak of the simple animal forms, or of the tissues of the more complicated; mortification is less frequently the result of venous than of arterial obstruction. Unquestionably turgescence and inflammation may ensue from the former, and may terminate in gangrene; but it is far more common for the part to be relieved by the excretion of various fluids, constituting hæmorrhage and dropsy, until new channels are found for the returning blood. Hence it appears that a redundance of fluid is less dangerous to organic structures than a deficiency.

Depravation of the fluid of nutrition.—It is obvious that as the structures are elaborated either from the blood in the higher animals, or from the fluids corresponding to it in the inferior classes, the assimilative processes must be deranged and ultimately brought to a stop, if the liquids are wanting in the proper materials. Their quality may be deteriorated in various modes; by imperfect respiration, by bad or scanty alimentation, and by insufficient or excessive excretion. Each of these causes is traced easily enough in the degenerated textures of some animals, but with more difficulty in the simpler classes, because the functions just alluded to are not in the latter concentrated within a space that admits of analysis so well as in the former. The effect of obstructed aeration of the blood however is soon mani-

* Edwards, On the Influence of Physical Agents, &c. translated by Drs. Hodgkin and Fisher.

fested even in the lowest grades. But we must observe, that throughout the whole range of animal existence we can more readily ascertain the changes produced in molecular action by *diminished* respiration, than by the entire suspension of this function; because, in the first place, the arrest of the circulation so soon follows that of respiration, that the subsequent events are assignable rather to the former than to the latter; and in the second place, it is impossible to cause one portion of the body to receive unaerated, while the others are supplied with aerated blood, since the function is in some animals too concentrated to allow of an operation calculated to act upon an isolated part, and in other animals too diffuse to enable us to interfere with it effectually in any given space. In the one case we run the risk of cutting off the supply of blood from the whole animal; in the other we should find it impossible to prevent any one part from receiving from other parts a compensation for what it loses by the obstruction of its own particular allotment of the respiratory function. Nothing however is more common than to witness the degeneration of structure produced by blood insufficiently arterialized, the imperfection of the process depending either upon disorder in the organs of respiration, or upon a vitiated condition of the atmosphere. From facts of this nature it is legitimate to infer that were it possible for unarterialized blood to circulate, the death of the tissues must sooner or later ensue. Of the destructive tendency of blood depraved by the other causes above enumerated we can likewise judge approximatively; in other words, while there can be no question of the deterioration of structures under the operation of those causes, we are not acquainted with any instances in which we can attribute solely to their agency the entire cessation of molecular actions. It almost always happens that other functions have previously failed, and influenced the result in question.

Extinction of irritability.—Irritability might at first seem rather the result of vitality than one of its conditions; but whether we look at the textural motions in a complex animal, or at their analogues in the entire systems of the simpler forms, we shall find irritability to be essential to the continuance of those processes in which living action consists. The alimentary cavity which contracts upon the nutrient fluid of the zoophyte is no less essential to the existence of the latter, than a similar action of capillary tubes in the tissues of mammalia. In each case the action is requisite, in order to bring the particles within the spheres of the textural affinities. The extinction of irritability is therefore necessarily productive of molecular death. In this instance we are compelled to speak of the privation of a property instead of defining the actual change in the part, because at present it is not ascertained what condition of the part is capable of producing contraction. Irritability is merely an expression of the fact that the substance of which it is predicated, undergoes contractions inexplicable on common physical principles. We detect nothing in the substance, the existence of which enables us to pronounce with certainty that it may be the subject of the actions alluded to. Some have maintained that irritability ought to be admitted as an ultimate fact, of which we know as much as of gravity. But we apprehend that there is this great difference in our knowledge of the two properties, viz. that although ignorant of the cause of the attraction of gravitation, we are certain that the phenomena are coextensive with the essential properties of matter; but we are utterly unacquainted with that collection of properties to which irritability necessarily belongs. The muscle which has ceased to quiver under the galvanic wire is, for all that we can tell to the contrary, the same in composition as that which is still capable of exhibiting the phenomenon. Moreover the action is observed in a great variety of tissues, both in individual animals, and in the whole series; tissues which appear to have little in common saving a fibrous arrangement of their particles. But as the action in question is stopped by causes which in no way affect the fibre as such, it is plain that this is not the only requisite. Moreover there are unequivocal exhibitions of contractility in animals, in which it is difficult to imagine that there can be any shortening of fibres; we allude to the Infusoria, Rotifera, Medusæ, &c. Tiedemann makes a separate species of this contractility, under the designation of "contractilité des animaux gélatineux."* There is reason to suspect that ganglionic tissue is importantly concerned in the action, partly because it is *almost* universally distributed through irritable substances, and partly because contraction is prevented by causes which operate upon this tissue. As long however as there are animals which manifest contractions, but in which no such tissue can be detected, it is impossible to consider the latter an essential element in the action generally; though it may be quite essential in the animals in which it is found; just as a heart, though by no means necessary to the function of circulation in the abstract, is indispensable in the animal of whose system it forms a part.

Irritability may be destroyed by substances, either applied directly to the part or acting upon the general system. Thus, the fibres of the heart may be paralysed by a solution of opium injected into its cavities, or by essential oil of tobacco given by the mouth. Lightning annihilates the property all over the body. The motions of Infusoria may be arrested by a shock of galvanism,† by solutions of opium and camphor, and by the vapour of sulphur. Arsenical preparations have a similar effect. The contractions of capillary vessels in the higher animals may be arrested by a certain description of injuries of the brain and spinal marrow.‡ But it is needless to multiply examples.

* Traité complet de Physiologie de l'Homme, traduit de l'Allemand par A. J. L. Jourdan, D.M.P. 2de partie, p. 782.

† Tiedemann, p. 617.

‡ See Wilson Philip on the Vital Functions.

Such then are the causes of molecular death. For a history of its phenomena, when partial, we must refer to the article MORTIFICATION. Its characters when universal, that is, when the consequence of systemic death, will be considered when we come to speak of the signs of the reality of death.

SYSTEMIC DEATH.

Systemic life is constituted by those actions which maintain the mutual dependence of the several parts of the organic whole. Such are the functions which provide new matter for the blood, (digestive secretion and absorption)—that which effects a chemical change in the blood, (respiration)—that which distributes it through the organs and tissues, (circulation cardiac, arterial, capillary, and venous)—that which removes from the blood effete matters, (excretive secretion)—and that which is intimately connected with all these functions, though we are ignorant of the mode of its operation, viz. the function of nervous matter or innervation. The cessation of these actions, and the consequent solution of connection between the various parts of the body, is systemic death. With the cessation of the remaining functions, or those which maintain certain relations between the organic body and objects external to it, constituting the animal life of Bichat, and the relative life of others, we have nothing to do in this place. (See SLEEP.)

The obstruction of any one of the functions above enumerated must in a longer or shorter space of time bring the others to a termination. But, as the arrest of the circulation acts upon the other functions immediately, while the latter affect one another merely by the intervention of the former, we may very properly consider the causes of systemic death under the general head of Syncope.

1. *Syncope by asphyxia.*—We shall not stop to inquire in what manner the suppression of respiration arrests the action of the heart, as the question has been very fully and satisfactorily considered in the article ASPHYXIA. For the same reason we shall waive the discussion of the accidental causes of this state, viz. strangulation, submersion, &c. &c. The diseases which are said to produce death by asphyxia are those in which syncope would not supervene when it does, but for the obstruction of the respiration. They are for the most part affections either of the respiratory apparatus itself, or of the brain and spinal marrow; and it is almost superfluous to add that they prevent the intercourse between the blood and pure air, either by blocking up the air-passages, or by stopping those muscular actions which are essential to a change in the contents of the pulmonary tubes and cells. Certain organic diseases of the heart itself are said to produce death by asphyxia. In these cases there is an obstruction to the motion of the blood through the left side of the heart; and in the majority of them the asphyxial symptoms are not so much the direct effects of the impediment in the heart, as of the intermediate pulmonary affections, some of the most frequent of which are bronchitis, œdema of the lung, and pulmonary apoplexy. When, however, a person dies suddenly, with asphyxial symptoms resulting from an arrest of the circulation at the left side of the heart, without any intervening derangement in the organs of respiration, the case ought not to be considered an instance of genuine asphyxia. The appearances imitative of this state (we allude more particularly to various phenomena belonging to venous congestion) are not occasioned as in true asphyxia by the stagnation of blood in the extremities of the pulmonary arteries, the consequence of its not being arterialized, but by the obstacle presented to the currents in the trunks of the pulmonary veins by the lesion of the heart. In brief, the anatomical difference in the two states is, that in the one the pulmonary arteries only, in the other both these and the pulmonary veins are the seats of congestion; the physiological distinction is, that in the former the obstruction is chemical, in the latter mechanical.

2. *Syncope by nervous lesions.*—The various parts of an animal body are bound together by a reciprocity of action, over and above that particular connection which exists between certain organs, and which results from a mutual subservience of function. In the latter, the association is perceptible in the normal condition of the body, as, for instance, between the organs of digestion and those of secretion, or of digestion and sanguifaction, or in the sympathetic actions of the respiratory muscles; but the other species of connection is only or chiefly observed in morbid conditions; in other words, it is only when danger is threatened to one organ that the others give tokens of their intimacy and of their interest in its well-being. But for our knowledge of the existence of this community of feeling (a phrase to be taken only in a metaphorical sense), it would be impossible to throw any light upon the fatal consequences of a great number of diseases and injuries. There can be little doubt that in all states of the system it contributes very materially to the production of that *individuality* which is one of the grand characteristics of organic beings, and which becomes more and more obvious as our survey rises to the higher departments of the animal kingdom. There is a manifest inequality in this respect, even among the superior classes of animals. Many lesions that would be fatal to birds and Mammalia, are comparatively trivial to reptiles, not so much because the injured part is of less importance in the functional arrangements of the latter, as because other parts have less sympathy with it.

There is no subject in the whole range of Physiology more beset with difficulties than the inquiry into the causation of sympathy. Vascular connection has been thought by some to explain the secret sufficiently, by others the contiguity or continuity of tissues. Some have seen the media of communication in the ganglionic nerves, others in the nerves called respiratory. We cannot enter into the discussion, and therefore refer to the article SYMPATHY. But we beg to state that we have no where seen the subject treated with more erudition and acuteness, than in Dr. Fletcher's Rudiments of Physiology.*

But while there can be no question that all the organs are more or less related in the manner above indicated, it is not less evident that the connection between some is of a far more intimate nature than between others. It is almost needless to instance the brain and the stomach, the brain, spinal marrow, and the heart, the heart and every part of the system, &c. &c. By overlooking the sympathetic relation between the brain and the heart, Bichat fancied that when he had proved the functional independence of the latter organ, he was compelled to search in some third part for the link between the death of the one and that of the other.† It cannot be denied that in a large proportion of cases, the syncope which follows lesions of the cerebro-spinal system, is not a direct consequence, and that there is an intermediate suppression of the function of the lungs,—that in other words the syncope is the effect of asphyxia.‡ (See ASPHYXIA.) It is somewhat remarkable that the illustrious physiologist just mentioned should have forgotten certain pathological facts which afford convincing evidence that cerebral injury may produce death without developing the phenomena of asphyxia; the "apoplexie foudroyante," for example, and the concussion of a blow or a fall. Nor is it less surprising that in his numerous experiments upon animals he should not have noticed what was afterwards fully demonstrated by Legallois and W. Philip, that both the heart and the capillaries may be immediately paralysed by violence done to the brain and spinal marrow. It must be remembered, however, that this result is much affected both by the extent and by the nature of the injury. Thus the brain may be sliced and the spinal cord divided, with no other influence upon the circulation than that which depends upon the interference with the respiratory actions; but laceration or crushing of the cerebral matter is immediately felt by the heart and capillaries. In these cases the circulation ceases, not because the cerebro-spinal axis takes any part in that function, but because it is connected with the heart in the same manner as we have stated that all the parts of the body are more or less connected,— in bonds of *alliance* though not of *dependence*. We have reason, however, to believe that the intimacy of the alliance between the brain and the heart is scarcely equalled by that of any other organs in the system.

* Part ii. chap. vi.

† Recherches sur la Vie et la Mort, art. xii. §2.

‡ We must not forget that even in many of these cases there is no immediate communication of injury from the part primarily affected to the organs of respiration. Thus, when a slight hemorrhage in one of the hemispheres of the brain occasions asphyxia, we are bound to believe that there is in the first place a *sympathetic* communication of derangement to the medulla oblongata, unless the hemorrhage has been so considerable as to cause compression of the whole encephalic mass.

The anatomical characters of syncope by nervous lesion are determined by the modus operandi of the injury. If the latter arrests the action of the heart only by obstructing the respiratory movements, the appearances are those of asphyxia, (see ASPHYXIA.) But if the operation be immediately upon the heart, there will be a difference in the appearances, — a difference which likewise belongs to all cases in which the circulation ceases without previous obstruction of respiration. The blood, instead of being accumulated in the right cavities of the heart, and in the pulmonary arteries, is more equally distributed between these and the left cavities, and the pulmonary veins. There is generally a perceptible difference in the colour of the blood in the two sides of the heart, but somewhat less than might at first be expected. The defect of arterial tint in the coagula of the left side may be fairly attributed to the draining away of the serum, and consequently with it of the saline particles upon the presence of which the red colour depends. Blood is found in the aorta and in many of the arteries. The signs produced by venous congestion, such as engorgement of the liver and spleen, turgescence of the cerebral veins and of those of the mucous membranes, are wanting, as well as the tumefaction of the face, the puffing of the lips, the projection of the eyes, and the deep lividities characteristic of that condition. We must remember that the appearances are considerably modified if syncope has taken place gradually. In such instances the heart is generally found empty. The cause of this condition is obvious. In the first place, as the degree of the diastole must be proportionate to the systole, it is obvious that when the latter is enfeebled, less blood will be received into the cavities; and, secondly, as less blood is driven into the pulmonary artery and the aorta, there will be less to return in a given space of time, and consequently there will be less impetus in the returning currents. It is easy to perceive that before the final and feeblest contraction, which must be succeeded by a correspondently slight dilatation, the current of blood pressing for admission must be very trifling.

3. *Syncope by injuries of the heart itself.*— This is of too obvious a nature to require comment.

4. *Syncope by injuries of other organs and tissues.*—When death follows quickly upon a lesion which does not necessarily implicate the vital organs, properly so called, we say in general terms that a shock has been given to the nervous system, in consequence of the strong probability that some portion of this system is the agent of sympathy. If violent pain attends the injury, and to this succeeds loss of consciousness, and then cessation of the heart's action, it is fair to infer that the brain was first operated upon through the nerves of sensation, and that the derangement of this organ affected the circulation. But there are

cases of injury in which syncope occurs without any antecedence of pain or of leipothymia, and in which there is no reason for supposing any cerebral affection in the chain of events. Of this kind are extensive mechanical injuries of the extremities, burns, rupture or over-distention of the stomach, &c. Whether the nerves which convey the morbid impression belong to the ganglionic or to the respiratory class, we do not profess to decide. The immediately fatal effect of a blow upon the epigastrium or of a draught of cold water when the body is heated, has been attributed by some to a shock given to the semilunar ganglion, and the communication of the impression to the heart; while others are of opinion that the injury is fatal by "paralysing the whole respiratory set of nerves from the violent shock communicated to the phrenic, and thus shutting up as it were the fountain of all the sympathetic actions of the body."* "A blow on the pit of the stomach," says Sir Charles Bell, "doubles up the bruiser and occasions the gasping and crowing, which sufficiently indicate the course of the injury—a little more severe, and the blow is fatal. A man broken on the wheel suffers dreadful blows, and his bones are broken, but life endures—the coup-de-grace is a blow on the stomach."

5. *Syncope by mental emotion.*—Instances of this occurrence must be familiar to every one both by reading and by observation. In some of them the cause in question has operated either by aggravating some pre-existing malady, or by calling into action some strong predisposition to disease; as in structural lesions of the heart on the one hand, and in the apoplectic diathesis on the other. But in other instances the mere violence of a passion has at once extinguished its subject without the intervention of morbid tendency or of actual disease. Such cases belong to the Nervous Apoplexy of some authors; and certain it is that they present a complete annihilation of sense and motion, but this condition is only simultaneous with, or immediately succeeded by the failure of the circulation. We have no doubt that the change in the organ of the mind, corresponding to the emotion, operates upon other parts of the cerebro-spinal axis, which in their turn affect the heart in the same manner as other preternatural states of that system. We are not acquainted with any example in which either high intellectual excitement unaccompanied by vehemence of passion, or mere intensity of external sensation, has been the cause of sudden death; nor could it be expected a priori, since in the normal condition of the economy there is by no means the same degree of connection between the action of the heart and intellectual and sensific conditions, as between the former and the emotions and affections.

6. *Syncope by hæmorrhage.*—The functions of the brain are in man so dependent upon a regular supply of blood to the organ, that a sudden diminution of it is alone sufficient to occasion vertigo and unconsciousness; and this occurrence often takes place when the action of the heart itself is little or not at all affected. Every one is acquainted with the effect of a change in the relative quantity of the blood in the cerebral vessels, determined by suddenly rising from the recumbent posture. Now it has been often observed that vertigo induced by other causes has been followed by suspension of the circulation; that is to say, the state of the brain, which was attended by giddiness, arrested the motions of the heart. It has therefore been inferred that loss of blood operates indirectly upon the heart through the affection of the brain. When two phenomena follow each other in such quick succession as to be all but simultaneous, it is difficult to determine which is cause and which is effect, or whether they may not be the common effects of some other event. Certain facts would seem to indicate that the latter is the true interpretation of the phenomena which we are considering. Thus hæmorrhage sometimes affects the nervous system in the manner alluded to, without presenting any check to the contractions of the heart; not to mention that it appears more consistent with analogy to conclude that the heart must be more directly influenced by the loss of that which is its natural stimulus, than by a change in a remote organ. Again, there are cases in which hæmorrhage makes a decided impression upon the organs of circulation before the brain has given signs of any material derangement of its functions; but in these the loss of blood is more gradual than in the former instances. "When hæmorrhage is very gradual," says Dr. Alison, "all the indications of failure of the circulation may come on—the feebleness of muscular action,—the paleness and collapse of the countenance,—the coldness beginning at the extremities,—the cold sweat beginning on the face,—and the pulse may become imperceptible; without the senses or the intellect being impaired, and a slightly laborious or heaving respiration may be almost the only indication of injury of the nervous system up to the moment of death."* From facts of this description we should be willing to decide at once that it is a superfluous multiplication of causes to attribute the stoppage of the circulation in any case of hæmorrhage to the influence of cerebral changes, when the direct operation of the cause upon the heart itself is adequate to the explanation;—were it not for the important fact that hæmorrhage alone often fails to produce syncope till some circumstance has intervened, the operation of which is manifestly upon the nervous system. Thus nothing is more common in bloodletting than to find the heart unaffected by the withdrawal of a considerable quantity of its stimulus, so long as the posture of the body is horizontal; but on raising the head, a change which for obvious reasons renders the brain

* Dr. Fletcher, op. cit. part ii. chap. 6. p. 60.

* Outlines of Physiology and Pathology, p. 344. This work contains a most valuable chapter upon the causes of sudden death.

more sensible of the loss of blood, the nervous symptoms, viz. vertigo and leipothymia, appear, and immediately afterwards the pulse falls and becomes imperceptible. In corroboration of this fact we might at first be inclined to mention that a diminution of the quantity of the blood, so far from depressing the circulation, often appears to excite it violently, as in what has been denominated *hæmorrhagic reaction;* but in such instances analogous effects have been also witnessed in the cerebral functions, namely, delirium and extreme sensibility, &c. On the whole we may conclude with regard to both these systems that the depressing effect of hæmorrhage depends rather upon the suddenness of the change, than upon the absolute diminution of the quantity of the fluid.

7. *Syncope by poisons.*—Some substances depress the action of the heart in the manner to which we had occasion to refer when speaking of syncope by mechanical injuries of the tissues generally. Of this kind are the mineral acids, oxalic acid, and the pure alkalies. They produce death, when taken in certain quantities, by means of that depression of the circulation which follows the destruction of the parts to which they are applied. In smaller quantities they may be more remotely fatal by exciting disease, gastro-enteritis for instance. One of the substances mentioned, viz. oxalic acid, may induce direct depression of the circulation, unattended by cerebral affection, even when its chemical effect upon the stomach is prevented by dilution. In this form it must be classed with a large collection of substances which in certain doses subdue the moving powers of the circulation, without any previous coma, without any alteration of the tissues, and without any gastric irritation; such are arsenic in large quantities, tobacco, digitalis, and most of the animal poisons. To the same class belong those malarious and contagious poisons which occasionally induce fatal syncope before any of their ordinary effects upon the general functions; we scarcely need to mention cholera, malignant typhus, plague, scarlatina, &c. The narcotic substances manifestly act first upon the cerebro-spinal system; syncope follows either with or without asphyxia. Those which act rapidly appear to strike the circulation before asphyxia has had time to transpire; we may instance hydrocyanic acid, essential oil of almonds, large doses of opium and of alcohol, certain gases, particularly sulphuretted hydrogen and cyanogen.

8. *Syncope by cold and lightning.*—It is not clear whether these outward agents arrest the circulation through their influence upon the nervous system, or by directly paralysing the irritability of the fibres of the heart.

9. *Syncope by inanition.*—In cases of this description it is probable that the failure of the heart's action is a compound result of the prostration of the nervous system, and of the diminution of the proper stimulus of the circulation.

10. *Syncope by disease.*—All fatal maladies must terminate in cessation of the heart'sa ction, but we limit the present category to those cases in which this event is unpreceded by asphyxia. The others have been hinted at under the head of syncope by asphyxia. The diseases now under consideration may, we think, be conveniently arranged as follows:— 1. Those which stop the motion of the heart by obstructing its mechanism, *e. g.* collections of fluid in the pericardium, lesions of the valvular apparatus; accumulation of fat, &c.; or by diminishing the contractility of the fibres, *e. g.* atrophy, or degeneration of the muscular substance;* or by perturbing in some unexplained manner the nervous influence, *e. g.* the functional form of angina pectoris. 2. Those which are attended with hæmorrhage, *e. g.* aneurisms, and diseases of mucous surfaces. 3. Those which induce excessive and long-continued discharges. Thus fatal syncope has suddenly terminated a fit of diarrhœa; but it must be borne in mind that in such instances the power of the circulation had previously been greatly enfeebled either by deterioration of the blood, or by causes acting on the innervation of the heart, or by the existence of irritation in some part of the system. 4. Diseases implicating the cerebro-spinal organs. Some of these operate in the same manner as those accidental injuries which produce concussion, and which have been already adverted to. Thus in that species of apoplexy which terminates instantaneously, (*apoplexie foudroyante* of French authors,) the sanguineous extravasation appears to have the same effect as a mechanical shock to the whole nervous mass. The more common form of apoplexy extinguishes life by impeding the respiratory movements. We have more than once known cases of structural disease of the brain terminate by sudden syncope, but have learned nothing from the necroscopy capable of explaining why the fatal occurrence took place at the precise time when it did, rather than at any other moment in the period during which the disease had existed; though it was easy to conceive that a lesion of this description must have been competent at any time to produce such changes in the cerebral circulation as would induce the result in question. 5. Diseases attended with what has been vaguely called *irritation*, either short and intense, or moderate but long-continued. This irritation consists sometimes of inflammation and its sequelæ, and sometimes of specific structural alterations. A good illustration of the former of these is afforded by peritonitis, which frequently cuts off the patient by subduing the action of the heart, long before this effect could transpire from derangements of the organs contiguous to the seat of disease. Still more remarkable in this point of view are the effects of acute inflammation of a synovial capsule. It is true that these affections are accompanied by violent pain, which might be said in common language to exhaust the powers of the system, or in stricter phrase, to

* See Mr. Chevalier's interesting cases of sudden death in the Med. Ch. Trans. vol. i.

produce a change in the nervous system incompatible with the continuance of the action of the heart; but mere pain will not account for the fact in question, since in other diseases it attains a more intense degree, and lasts longer, as in neuralgia, without inducing fatal consequences. The causation is probably analogous to that of syncope from mechanical injuries of tissues, to which we have already devoted some remarks. But why an inflammatory condition of serous membranes should exert a more depressing influence upon the circulation than that of many other tissues that might be named, is a subject wrapped in deep obscurity; yet it is scarcely darker than the question, why such changes should in the first instance excite and perturb the heart, or why a similar excitement should ensue upon the softening of a cluster of tubercles, and to a degree inexplicable by the functional derangement of the part in which the tubercles exist. Diseases in which the powers of the system are said to be *worn out*, are in reality such as have gradually enfeebled the action of the heart, partly perhaps through the intervention of changes affecting the blood, the respiration and the nervous system, but probably in a great measure by as direct a relation between the diseased part and the change in the circulation, as between violent lesions of tissue and syncope. Under the present head are included a host of chronic maladies. 6. Diseases *caused by* vitiation of the blood. Such are scorbutus, certain forms of marasmus, the cachexiæ revealed by dropsies, and certain fevers of a malignant character. We might also mention those depravations indicated by morbid secretions, such as tubercle, carcinoma, melanosis, &c. but that the solids are so much involved in these diseases, that it becomes difficult to determine whether the heart's action was weakened by the primary lesion of the blood, or by the secondary one of the tissues. 7. Diseases *which produce* vitiation of the blood. Such are that large class in which there is disorder of the chylopoietic processes, and that smaller group in which the conveyance of the chyle is impeded. Derangements of the secernent and excernent organs must be arranged in this division, and particularly those of the liver, the skin, and the urinary apparatus. Diabetes is a state of the system in which the blood is probably deteriorated both by defective assimilation, and by faulty excretion. Upon the whole of this class of diseases it must be remarked that we seldom or never have opportunities of witnessing their uncombined influence in depressing the organs of circulation.

11. *Syncope by old age*.—We have, in a former article (Age) endeavoured to trace the principal events in senile decay. The death which follows this gradual decline of the functions, presents the strongest possible contrast to that of sudden syncope. In the latter instance the assault is made upon the very citadel of life, the conquest of which secures an immediate surrender of the minor bulwarks and dependencies; but in the former the fortress is reduced only after a long series of defections in the outworks, and a consequent loss of supplies, or, to quote the words of an illustrious author, "Voici done la grande différence qui distingue la mort de vieillesse, d'avee celle qui est l'effet d'un coup subit; c'est que dans l'une, la vie commence à s'éteindre dans toutes les parties, et cesse ensuite dans le cœur; la mort exerce son empire de la circonférence au centre. Dans l'autre, la vie s'éteint dans le cœur, et ensuite dans toutes les parties; c'est du centre à la circonférence que la mort enchaîne ses phénomènes."*

SIGNS OF APPROACHING DEATH.

It would be tedious and altogether beyond the compass of this work to enumerate all the phenomena presented by the dying system, since they vary with the cause of death. We shall aim rather at describing and aceounting for those which are common to most diseases and to natural decay; reserving to ourselves the liberty of noticing here and there some of the more striking varieties.

We might rationally expect that the first indications of dissolution would appear in the relative functions; hebetude of the senses, inaction of the muscles, vacancy of the intellect, extinction of the sentiments; and such is, in fact, the course of events in natural death. We have known the aged man remain feelingless, motionless, mindless, for many days before the cessation of the organic functions. This kind of death is sometimes imitated by apoplexy; but in the former the destruction of the animal life does not, as in the latter, arise from a lesion of the brain; its organs appear to undergo a gradual process of enfeeblement. In many febrile maladies there is the same priority of failure on the part of the cerebral functions, but they are generally preceded by more or less actual disease of the organ. But in the termination of some disorders the functions alluded to continue to the very last, almost surviving the circulation itself. It will be found however that the seat of such disorders was remote from the encephalon, that it did not communicate with the latter by any special sympathy, and that the extinction of the cerebral functions was attributable to the arrest of circulation in that organ, in common with many others. The cases in which the mind is said to continue clear and vigorous amid the ruin of the body, will be found to agree in the fact that the organ is correspondently unimpaired; they are for the most part chronic diseases of the thorax, abdomen, pelvis, and extremities. Certain affections even of the cerebro-spinal system may not interfere with the understanding and feelings until almost the last moments; but they are such as do not involve those divisions with which thought is believed to be more immediately connected: we may instance tetanus. But although in these maladies we do occasionally observe considerable intellectual soundness till within a very short period of death, we have far more commonly been able to detect some degree of delirium, an

* Bichat, Rech. sur la Vie et la Mort, p. 151.

exaltation of one part of the mental constitution at the expense of the others. Excitement of the imagination has, we doubt not, been frequently mistaken for general mental vigour. We should place such instances, however, far below those in which there remains sufficient steadiness of the understanding to direct the provisions of a will; though by many observers such a condition of the intellect would be considered a far slighter evidence of the triumphs of mind over matter, than the impassioned expressions to which the dying man sometimes gives utterance, when describing the visions of his phantasy.

The delirium of the dying is often of a most interesting character, and resembles dreaming more than any other form of derangement that has fallen under our notice. The ideas are derived less from present perceptions than in insanity, and yet are more suggested by external circumstances than in the delirium of fever and phrenitis. Thus the sight of a bystander often suggests the image of a friend long departed, in which character the moribund man addresses him, and talks earnestly of persons, scenes, and events belonging to a former period of his history as if still present. The vivified conceptions are generally derived from subjects which either in his speculative pursuits, or in the business of life, have principally occupied his thoughts. The last words of Dr. Armstrong were addressed to an imaginary patient upon whom he was impressing the necessity of attention to the state of the digestive organs. We have heard that a great legal officer not long deceased, having raised himself for a moment from his couch, said with his wonted dignity, "Gentlemen of the jury, you will find,"—and then fell back on his pillow and expired. The visual conceptions reproduced in some minds often appear to have been derived from poetical reading. We remember hearing a young man, who had been but little conversant with any but civic scenes, discourse most eloquently a short time before death, of "sylvan glen and bosky dell," purling streams, and happy valleys; "babbling of green fields," as if his spirit had been already recreating itself in the gardens of Elysium. It not unfrequently happens that the spectra owe their origin to contemplations of future existence; and consequently that the good man's last hours are cheered with beatific visions and communion with heavenly visitors.

> "Saw ye not even now a blessed troop
> Invite me to a banquet, whose bright faces
> Cast thousand beams upon me, like the sun?
> They promised me eternal happiness,
> And brought me garlands, Griffith, which I feel
> I am not worthy yet to bear: I shall assuredly."
> *King Henry VIII. Act* iv. *Sc.* 2.

Dreadfully contrasted with such visions are those which haunt the dying fancies of others. The previous habits and conduct of the individual have sometimes been such as to incline spectators to enquire whether in the mode of his departure from existence he might not already be receiving retribution; just as, in other cases, celestial dreams and colloquies have seemed fitting rewards for blameless lives and religious meditation. It would be presumptuous, however, to hazard much upon the final causes of the various modes of terminating the career of life, not only for certain obvious general reasons, but also because we have known both the virtuous and the vicious pass away in states of unconsciousness, to all appearance precisely similar.

One of the most curious instances of derangement that we have met with occurred in a phthisical patient. It consisted in a morbid association of ideas by mere similarity of verbal sound, or in other words a propensity to rhyme. Every person who came to the bedside was sure to receive a distich in honor of his name; nor could any remark be made in his presence without his seizing one of the words uttered and finding a rhyme for it, in doing which he exhibited great ingenuity. We were unable to ascertain whether he had been addicted when in health to attempts at metre. Recitations of poetry, appearing to recur from a passive process of memory, with perfect unconsciousness of what is passing around, are frequent occurrences; and the passages selected have often a singular coincidence with events in the life of the moribund rehearser. Sir W. Scott's touching picture of the death of Madge Wildfire has had many unfictitious counterparts.

Dementia or imbecility sometimes comes on a short time before death. It is for the most part manifested by an incapacity of concentrating the ideas upon any one subject, and by an all but total failure of memory. The study of the degree of this condition necessary for invalidating a legal document is of great importance to the medical jurist. The mental weakness is in no respect so painfully exhibited as in the facility with which the subject of it derives pleasure from puerile amusements. "Playing with flowers" is a token of approaching dissolution enumerated by a dramatic author, one whose observation pervaded human nature in all its phases. We remember visiting a lady in the last stage of a urinary disorder, during the progress of which she had evinced both strength of mind and refinement of taste:—we found her arranging with great care, and with demonstrations of delight at her success, a garland of flowers around a chamber utensil. A more humiliating spectacle could scarcely be witnessed. We augured that her decease was near at hand, and she died on the following day.

In the delirium under consideration, reproductions of visual sensations bear a considerable part; but in some cases the consciousness is exclusively occupied by them;—they are mere ocular spectra. Thus with a vacant countenance, half-shut eyes, and gaping mouth, and in a state of insensibility which no outward impression can rouse, the victim of typhus is seen catching at something in the air. By the adjustment of the finger and thumb, it is evident that the imaginary objects are often minute; and it is not unlikely that they produce a kind of annoyance like that of *muscæ volitantes*, which the hand is instinctively attempting to remove. Whether the production of such spectra depends upon changes in the retina, or upon changes in the cerebral extremity of the optic nerve, is not altogether certain; but we incline to the latter view, principally because other sensations are often revived though the nerves in which they originated have been paralysed or removed.

Renewals of perceptions of hearing are not uncommon. Such are imaginary voices, and sounds of tolling bells, &c.

No reason has been assigned for that symptom noted by the earliest observers—"picking of the bed-clothes;" or, in Dame Quickly's phraseology, "fumbling with the sheets." But we think it may be readily accounted for as resulting from revivals of tactual sensations, which produce corresponding movements, so that the fingers grasp the bed-clothes in mistake for the imaginary substance. Something analogous to this is witnessed in delirium tremens, a disease in which visual conceptions are particularly liable to vivifaction in the form of animals, and in which also we have witnessed the patient picking the ends of his fingers as if to remove something disagreeably adherent.

Whether consciousness of bodily sensations continues till the very commencement of the death-struggle, or *agony*,* as it is termed, is an enquiry often put to the medical attendant either by patients themselves, or by their anxious relatives. The ideas entertained by persons unaccustomed to physiological study respecting the pains of dying, have arisen partly from their theoretical views of the nature of the event itself, and partly from their observation of its preceding or accompanying phenomena. When they imagined death to be a kind of forcible severing of the spirit from the body,—a separation so opposed to the inclination of the former that some have fancied it longing to return to the body,

——"iterumque ad tarda reverti
Corpora, quæ lucis miseris tam dira cupido:"

or like the shade of Hector,

Ψυχὴ δ' ἐκ ῥεθέων πταμένη Ἄϊδόσδε βεβήκει,
Ὃν πότμον γοόωσα, λιποῦσ' ἀδροτῆτα καὶ ἥβην.
Iliad. XXII. 362.

or when they regarded the throes of death as efforts of the confined inmate to escape from its tenement; or when laying aside their imaginings, they witnessed a heaving respiration, cold dew on the face, and convulsive agitations of the whole frame, affections so often known to accompany intense bodily suffering,—it is not wonderful that the process of dying should have been considered one of distress and anguish. But the practitioner ought to be able to console the friends of the dying by the assurance that whatever may have been the previous torture, it must be all over when once those changes begin in which death essentially consists. He must explain to them how upon the failure of the circulation, the function of the brain must cease by necessity; that if the cessation of the former be gradual, that of the latter may and often does precede it; that if the mortal process begins in the lungs, unconsciousness precedes the arrest of the circulation; and if in the brain, that an injury of this organ sufficient to affect the lungs and the heart fatally is sure to annihilate its own sensibility. The muscular spasms, the slow, gasping, or gurgling breathing, the collapsed or distorted features, though in some cases accompanied by feeling, are altogether independent of it. Convulsion is not, as superficial observers often interpret it, the sign of pain, or the result of an instinctive effort of nature to get rid of the cause of pain,—it is an affection of the motific not of the sensific part of the nervous system.* The pangs of the disease may last till within a short period of death, but it is a great error to attribute them to the process which brings them to an end. Such cases however are rare; it is far more common for the sensibility to be blunted, or for the cause of pain to subside before the phenomena of dying commence. A person poisoned by an irritant is said to die in great agony; a very incorrect expression, since death in such cases is ushered in by coma and by convulsions unattended with pain. Temporary syncope and asphyxia, the nearest approaches to actual death, have nothing formidable in sensation if we may judge from the reports of those who have experienced them; so far from it indeed, that some have described feelings of extreme pleasure, connected with each of these conditions.†

The relaxation and incapacity of the muscular system, though for the most part extreme, has in some cases been much less than might have been expected; and even chronic maladies, attended during their course with great emaciation and debility, have suddenly terminated when the patients were in the act of walking, or of performing some other exertion disproportionate to the rest of the functions. The condition of certain muscles in the last stage of existence will be alluded to when we come to speak of the general aspect and posture of the dying.

The voice is generally weak and low as death approaches, but sometimes has a shriller pitch than natural; sometimes it is husky and thick, and not unfrequently it dwindles to a mere whisper. These changes are caused principally by the debility which the vocal share

* The reader will scarcely need to be reminded that this word is used in its etymological sense, ἀγὼν, certamen.

* Dr. W. Philip has some excellent remarks upon this subject in his treatise on Sleep and Death.

† See Principes de Physiologie Médicale, par Isid. Bourdon, p. 319. [It was either Dr. Black or Dr. Cullen who told his attendant friends that "he wished he could be at the trouble to tell them how pleasant a thing it was to die." Ed.]

with all the other muscles in the system. Interruptions of the voice are obviously often due to the state of the respiration. It must not be omitted that in some instances the voice has remained firm to the last.

Of the signs of death derived from the organic functions, the first in importance are those belonging to the circulation. The mode in which the action of the heart declines is extremely various, but has for the most part some connexion with the nature of the disorder. In maladies of considerable duration, and in which for a long time all the functions have suffered in a greater or less degree, the cessation of the heart's motion is nearly always gradual. The number of pulsations may, within a brief period of decease, greatly exceed the natural rate, but their energy is impaired, and the quantity of blood expelled at each systole is very small. In many acute affections the failure is evidenced sometimes by increased frequency and diminished vigour of the contractions, and sometimes by their irregularity and frequency, the force being but little altered. In such cases the cause of disturbance is, without doubt, in some interruption of the nervous connexions of the organ. In other cases, the heart, before finally ceasing to beat, contracts with great violence, and then rapidly and suddenly comes to a stop. We have frequently noticed this kind of action in diseases of the brain, and have had reason to think that the syncope was brought on by the state of the respiration; the latter effect, however, being itself due in no slight measure to the irregular action of the heart.

The increased frequency of the pulsations in a debilitated state of the heart indicates a greater susceptibility to the stimulus of the blood, at the same time that the resulting contractions are less efficient. The period of repose between the diastole and the systole is briefer than in the normal action, besides that less time is occupied by the systole itself, in consequence perhaps of the very slight shortening of the fibres. In a vigorous heart the reverse of this takes place; the irritability is not such as to prevent a considerable pause after the diastole, and the fibres undergo a much greater degree of shortening. Why the irritability of a part should increase to a certain extent with increasing debility, is a problem yet to be solved. But we have reason to think that it is chiefly in acute diseases that the great rapidity of the heart's action is presented, and that in chronic affections there is a more gradual exhaustion of irritability. *Inequality* of arterial action, when amounting to a great degree, is one of the most threatening symptoms that can be witnessed. We allude particularly to that extraordinary pulsation of the carotids which is sometimes observable, when the radial artery can scarcely be distinguished. It is perhaps one of the strongest presumptions that arteries possess a vital contractility, which may be disturbed in them as in other parts of the system.

The state of the respiration in a moribund person is extremely various; sometimes hurried and panting till within a few moments of decease; sometimes ceasing gradually, in harmony with the languishing circulation; but sometimes slow, laborious, and stertorous, and, as Haller expresses it, "dum anxietas equidem cogit moliri, vetat debilitas."* In addition to those causes of struggling respiration which belong to the nervous centres and to the circulation in the lungs, the function is often dreadfully embarrassed by the accumulation of fluids, mucous, serous, or purulent, in the bronchiæ. The quantity of these secretions is often increased by a state of the bronchial membrane, analogous to what we shall notice presently in the skin, designated by Laennec "the catarrh of the dying;" but the mere accumulation of the natural quantity from defect of those muscular actions which usually remove it, whether in the fibres of Reisseissen, or in the general respiratory apparatus, is amply sufficient to cause exquisite distress. Mediate or immediate auscultation detects a loud guggling throughout the chest, which is sometimes audible even at a little distance, and the vibrations of which may be felt by the hand. This sound must not be confounded with the true "death-rattle," which is produced not by struggles between air and liquid in the bronchial ramifications, but by the ejection of air from the lungs through the fluid in the trachea. It is often followed by a flow of spumous liquid through the mouth and nostrils.

The loss of animal heat occurs first in the extremities,—a fact easily explicable by the smaller quantity of blood sent into them; but it is probable that the state of the nervous system, and the cessation of the nutritive and other capillary actions, which perform so important a part in calorification, may participate in the production of the result in question. The recession of heat from the limbs was noticed by Hippocrates, but his mode of stating the fact in one remarkable passage, his last aphorism, appears considerably affected by his theoretical views of the use of this agent in the economy.†

The secretions present nothing very characteristic. If the disorder has been of short duration, they may have undergone no considerable change; but when the declension of life has been more gradual, they are all more or less altered. The bile and the urine are often found in their proper receptacles, of a perfectly healthy character, after a short illness; while in senile dissolution they are almost always scanty and vitiated. The generation of gas in large quantities, so as to produce tympanites, is a very common occurrence at the termination of acute diseases.‡ We have also noticed loud borborygmi during the last few hours of life, occasioned by large collections of air, and by a preternatural excitement of intestinal irritability, analogous to what we have noticed in the heart and arteries. The

* Elementa Physiologiæ, lib. xxx. § 22.
† Hippocr. Aph. § viii. 18.
‡ Hipp. Aph. § viii. 17.

secretion of saliva is almost always suppressed, and the mucus about the mouth and nasal passages is so deficient, that the lips and tongue require constant moistening when articulation is attempted; not to mention the inextinguishable thirst which is one of the most painful forerunners of some forms of dissolution. The perspirable secretions are generally rather profuse than scanty. The cutaneous surface, particularly about the face, is bedewed with a clammy exudation. It cannot be said that the weakness of the circulation is the immediate cause of this circumstance, because it frequently happens in a very opposite state of the function. It is true that the latter fact has been explained by supposing a transudation of the thinner part of the blood through the coats of the capillary vessels during their distention, while the former has been attributed to a spasm of the same vessels, consequent on the diminished force of the circulation, and said to have the effect of squeezing out the same serous liquid. In each case we must presume the perspired fluid to be in a state of separation before the supposed agency can come into operation. The hypothesis is supported by little evidence; but we are not sure that any other interpretation can be found much more conclusive. It seems probable, however, that the fact in question results less from so mechanical a process as has been hinted at, than from a chemical alteration in the fluids, induced perhaps by a change of innervation, in a manner analogous to those extraordinary changes which the secretions so frequently present under the influence of mental emotion.

It remains for us to enumerate a few of the signs of approaching dissolution, derived from the general aspect of the body. Many of these have been described by Hippocrates with unrivalled accuracy. The sunken eyes, the hollow temples, the sharpened nose, the forehead dry, tense, and harsh, the complexion sallow, livid, or black, the lips cold, flaccid, and pale, or of a leaden hue—compose the celebrated *facies Hippocratica*.* All these signs admit of an easy rationale by the state of the circulation and of the muscular system. They are however in some measure due to the condition of the cellular tissue, which, independently of its loss of fat, is exhausted of that interstitial fluid, which in health contributes so much to the firmness and equality of the cutaneous surface. In proof of this we may mention that all the appearances enumerated may be produced merely by a violent illness of a few hours; by cholera for instance, a disease in which the serous fluid is rapidly drained from the system into one channel. Excessive fatigue and fasting will occasion appearances very similar, and therefore the Father of Medicine recommends us to ascertain whether such causes have been in action, before we pronounce the patient to be moribund. A partial closure of the eyelids and a gaping mouth are signs, when conjoined with the others, of fearful import. There must be an extreme depression of the nervous system when the orbicularis is unable to bring the lower lid into contact with the upper, which has drooped from relaxation of the levator palpebræ, and when the masseter and temporal muscles resign the lower jaw to gravitation. A supine position with the limbs extended, and a tendency to slide down to the lower part of the bed, are indications of mortal prostration. In the posture alluded to there is little or no muscular exertion; for the extension of the legs, when the body lies upon the back, is not necessarily maintained by the action of the extensor muscles, since the mere support of the surface on which they rest would keep them in that position. The sliding down in the bed is owing to the inability of the glutæal muscles to resist the gravitation of the trunk down the inclined plane, upon which this part of the body is extended when the head and shoulders are resting upon the pillow. When the prostration is less extreme, it often happens that instead of the extremities being carried forward by the impulse alluded to, the thighs are raised, the knees bent, the soles rest flat upon the bed, and the heels afford a sufficient resistance to the nates to prevent any further descent. It is evident that this position of the legs and thighs, though requiring a muscular effort for its production, needs little or none for its maintenance.

The moribund are often impatient of any kind of covering. They throw off the bedclothes, and lie with the chest bare, the arms abroad, and the neck as much exposed as possible. These actions we believe to be prompted by instinct, in order that neither covering nor even contact with the rest of the body may prevent the operation of the air upon the skin. There are actions and re-actions between the air and the blood in the skin, similar to those which occur in the lungs, and hence in asphyxial disorders the symptoms alluded to are very marked; but the mere influence of the air upon the cutaneous nerves has been proved by Dr. Edwards to be beneficial to the vital powers. Certain it is that these symptoms are sometimes prominent in cases where the respiration is very little involved in the mortal struggle. Orfila, in one of his cases of poisoning by sulphuric acid, mentions that the subject of it made constant efforts to remove even the lightest kind of covering.

The appearance of the face is by no means such as we have described it above, in all cases. The kind of death must always have a great influence on the expression. On fields of battle the corpses of those who died of stabs are easily distinguished by the countenance, from those who fell by gun-shot. In the former an extremely painful impression must have been transmitted to the brain, which produced the usual change in the nerves and muscles of expression; in the latter a concussion was given to the whole system, paralysing without any intermediate sensation, so

* These signs are not thus grouped together in the original, but are individually mentioned in the book "Προγνωστικον," not the "Περι νοίσων."

that no expression remained more than that of the repose of the muscles. The nature of the disease also modifies the facial expression of the dying. In some we observe the impress of the previous suffering, as in peritonitis and in cases of poisoning by irritants; in others the character is derived from a peculiar affection of some part of the respiratory apparatus, as of the diaphragm in pericarditis; or from an affection of the facial muscles themselves, as in tetanus and paralysis. But the condition of the mind is perhaps more often concerned in the expression than even the physical circumstances of the body. For, as some kind of intelligence is frequently retained, and strong emotions are experienced till within a few moments of dissolution, the features may be sealed by the hand of death in the last look of rapture or of misery—of benignity or of anger. Every poetical reader knows the picture of the traits of death (no less true than beautiful) drawn by the author of the "Giaour." But such observations are not confined to poets. Haller could trace in the dying countenance the smile which had been lighted by the hope of a happier existence: "*Adfulgentis fugienti animæ spei non rarò in moribundis signa vidi, qui serenissimo vultu, non sine blando subrisu, de vitâ excesserunt.*"* Watchers of the dead have often affirmed, and we can ourselves testify to the fact, that a smile has appeared upon the countenance some hours after death, though no such expression had been witnessed at the time of the event; which is not difficult of interpretation if we consider that an extremely slight muscular action is sufficient to give any kind of expression, particularly that of complacency,—that mortal rigidity is produced by a species of contraction in muscular fibres, (to be discussed more fully hereafter), and that this change seldom takes place till several hours after death.

SIGNS OF ACTUAL DEATH.

The discrimination of true from apparent death is not a matter of mere physiological interest. It is of great importance that the medical practitioner should be able to decide in doubtful cases whether the resources of art may be dispensed with, or the rites of sepulture be permitted, as well as to give evidence, in certain medico-legal inquiries, of the precise period at which an individual expired. We have not space to record the numerous cases that may be met with in various authors, proving that even the most sagacious and experienced observers have been at times deceived as to the reality of death. In the works of the ancients there are frequent allusions to premature interments. Pliny has a chapter, "De his qui elati revixerunt;" and among other cases mentions that of a young man of rank, who was revived by the heat of his funeral pyre, but who perished before he could be rescued from the flames. "Hæc est conditio mortalium," is the reflection of the philosopher, "ad hasce ejusmodi occasiones fortunæ gignimur, ut de homine ne morti quidem debeat credi." Celsus asks, "si certa futuræ mortis indicia sunt, quomodo interdum deserti a medicis convalescant, quosdamque fama prodiderit in ipsis funeribus revixisse?" "Complura fuerunt exempla," says Lord Bacon, "hominum, tanquam mortuorum aut expositorum a lecto, aut delatorum ad funus, quinetiam nonnullorum in terrâ conditorum, qui nihilominus revixerunt."*

In the writings of Winslow† and Bruhier‡ will be found an ample collection of melancholy instances of premature interment, besides those which are scattered through various systematic works upon forensic medicine. Unintentional vivisection, moreover, has befallen other instances than the celebrated subject of Vesalius. Few of our readers have not shuddered at the tale of the dismal fate of the Abbé Prevost, who, having been struck with apoplexy in the forest of Chantilly, was taken home for dead, but recovered his consciousness under the scalpel, and died immediately afterwards. We must not recount the marvellous recoveries recorded by French authors, of Madame Mervache, the wife of a jeweller at Poitiers, who was restored to life in her grave, by the attempts of a robber to despoil her of the rings with which she had been buried; and of Francois Civille, a Norman gentleman, whose custom it was to add to the signature of his name, "trois fois mort, trois fois enterré, et trois fois par la grace de Dieu ressuscité." The English reader will find an interesting selection of cases in the Appendix to Dr. Smith's Principles of Forensic Medicine, and in the article Premature Interments in the Encyclopædia Britannica. We shall only add that Bruhier collected fifty-two cases of persons buried alive, four of persons dissected prematurely, fifty-three of persons who recovered without assistance after they were laid in their coffins, and seventy-two falsely reported dead.§

We shall arrange the indications of death under three heads:—

1st. Signs of the extinction of vital functions and properties.

2dly. Changes in the tissues.

3dly. Changes in the external appearance of the body.

1. The arrest of the circulation and respiration would at first appear to afford decisive evidence that a person is no longer alive. But this sign is liable to the two-fold objection that we cannot distinguish with absolute certainty the minimum of the functions mentioned, from their complete annihilation, and that recoveries have taken place after their real or

* Elem. Phys. lib. xxx. § 23.

* Hist. Vitæ et Mortis, § x.

† Dissert. an mortis incerta sint indicia.

‡ Dissert. sur l'Incertitude des signes de la mort.

§ Louis in his Lettres sur la Certitude des signes de la mort, insinuates that some of Bruhier's cases are apocryphal. A more recent and perhaps a more authentic collection of cases will be found in M. Julia de Fontenelle's "Recherches médico-légales sur l'incertitude des signes de la mort," &c. 1834.

apparent cessation. The case of Colonel Townshend, related by Cheyne,* is too well known to need recital here. Perhaps the most unequivocal examples of their suspension are certain cases on record of restoration after submersion for several minutes. In some of these there is good reason to believe that there was no genuine asphyxia, but that syncope took place immediately, and consequently that there was no stagnation of blood in the extremities of the pulmonary arteries. As to the alleged cases of persons who have been said to lie many hours and even days without pulse or breathing, we do not hesitate to express a belief that the observers were deceived, and that in reality both these functions were performed, but in so low a degree as to escape detection, just as hybernating animals were supposed to be, during their torpor, in the predicament alluded to, until the researches of Dr. M. Hall proved that these animals do actually respire and maintain their circulation, though in a much less degree than when awake. It will be the duty of the practitioner to adopt every method within his reach of ascertaining the actual condition of these functions; but he must remember that they are often inefficient and even fallacious. Thus, with regard to the common modes of trying the respiration by a mirror, or by light downy bodies placed near the mouth and nostrils, it is obvious that the former may retain its clearness, because the halitus is not in sufficient quantity to stain it, or may be dimmed by exhalations from the air-passages which are not the products of respiration; and that the downy substances may be stirred by currents of air, or remain unmoved by the trivial exchange which takes place between the external atmosphere and the air in the chest of the person examined. Winslow's test of a vessel full of water placed on the lowest part of the thorax is of little utility, since we know that the diaphragm may be the only muscle employed in expanding the chest. As to the circulation, it may continue though no pulsation can be felt over the arteries or the cardiac region, and no sound be perceptible by auscultation mediate or immediate. Few practitioners would be willing to apply M. Foubert's test, to wit, that of making an incision in one of the intercostal spaces, and feeling the heart with the finger!

The loss of irritability in the muscular fibres is of far greater consequence than either of the foregoing signs. It may be present when recovery is out of the question, but its absence is quite conclusive. Galvanism affords a certain and ready method of detecting this property. According to the researches of Nysten† irritability is first extinguished in the left ventricle; after forty-five minutes it has left the intestines and stomach; a little later the bladder; after an hour the right ventricle; after an hour and a half the œsophagus; after an hour and three quarters the iris. It next takes leave of the muscles of the trunk, then the lower and upper extremities, and lastly the right auricle. The duration of contractility is shortened by a warm and humid state of the atmosphere, by ammoniacal gas, carbonic acid, and sulphuretted hydrogen. It is unaffected by carburetted hydrogen, chlorine, and sulphurous acid; nor is it found diminished in cases of asphyxia by strangulation and immersion. The annihilation of that particular kind of contractility of tissue, which is equally distinct from muscular contractility, irritability, and elasticity, is one of the surest signs of death. We see it wanting in the collapsed edges of a wound which has been inflicted on the skin of a dead body, as contrasted with the gaping appearance of a similar lesion made during life.

The loss of animal heat, though an invariable occurrence at some period after death, is not unfrequently noticed in disease. Every practitioner must have met with it in hysterical cases; and it is a matter of notorious observation in cholera. On the other hand we have known the heat of the body not only continue but even return at a considerable period after death has unequivocally taken place; a fact attributable either to chemical actions of a cadaveric description, or to the continuance of the processes which developed caloric during life. The mean time requisite for the complete cooling of the body is fifteen or twenty hours; but the process is modified by a great variety of circumstances. It is slower after acute than chronic maladies, but is very considerably retarded in asphyxial cases, except those occasioned by submersion.

Calorification is not the only function that may survive what is commonly called death; thus the rectum and bladder have been known very frequently to discharge their contents after death; and, which is still more remarkable, parturition has taken place under such circumstances. The continuance of secretion, absorption, and nutrition has been argued from the exhalation of serous fluids in some parts, their disappearance in others, and the alleged growth of hair. Some of these facts are more rationally explained on such physical principles as are involved in transudation, endosmose, penetration, &c. &c.; as to the growth of hair, there is great reason to doubt the accuracy of the testimonies to the fact. Haller very justly observes that shrinking of the skin would produce an apparent elongation of the beard, which is the part upon which the observation alluded to has been most frequently made.

2. The first alterations in the physical properties of the solids after death are softness and flexibility, to which succeed sooner or later the opposite conditions of firmness and rigidity. The softness or want of elasticity may be owing partly to differences in the distribution of the fluids in the tissues, and partly to changes in the tissue itself. The flattening of those parts upon which the weight of the body rests, the effect of deficient elasticity,

* English Malady, page 307.

† Recherches de Physiologie et de Chimie Pathologique.

is considered by Blumenbach a valuable criterion of the reality of death. The flexibility of the joints obviously depends upon the relaxation of the muscles.

Rigidity is a change which has attracted great attention from its importance as an evidence of death. Its period of accession depends principally upon the nature of the malady. After long and exhausting illnesses, its appearance is early, but the duration is brief, and the intensity trifling. The same remark applies to the modifying influence of old age. When the individual has been cut off by sudden accidental causes or by acute diseases, it comes on for the most part much later,* lasts longer, and is more intense than in the former instances. It may appear within half an hour after death or may be delayed twenty or thirty hours, according to the circumstances just mentioned. The mean duration is from twenty-four to thirty-six hours; but it may last six or seven days according to Nysten, whose researches upon this subject are very valuable. We remember observing it once on the eighth day after death in the body of a criminal who had been executed by hanging, but are not aware at what time it had commenced. The parts which first present this change are the neck and trunk; it then appears in the lower extremities, and lastly in the upper. Its departure observes the same order.

It is yet to be proved that rigidity is not an invariable consequence of death. Nysten attributes Bichat's assertion of its non-appearance in some cases of asphyxia, to the lateness of its developement. If it could be wanting in any case, it would probably be so in subjects attenuated and of flabby fibre. Louis in his Letters on the Certainty of the Signs of Death declares that he never found it absent even in the infirm and age-worn patients of Salpetrière, and Foderé gives a similar testimony to its universality.†

The seat of rigidity is the muscular substance. Of this we may be assured by the following facts. (1). It is observed in all those animals (including many of the invertebrata) which have a distinct muscular tissue. (2). Its intensity is in a direct ratio with the developement of this tissue. (3). It is destroyed by division of the muscles, a fact first noticed by Nysten.‡ (4). It remains when the cellular membrane, skin, aponeurosis, and ligaments are removed.§ (5). When very strong, it renders the muscles prominent as in voluntary contraction, or in that spasm which is induced by rammollissement of the brain and spinal marrow. Ch. Louis makes a remark of this kind in his admirable memoir upon some cases of sudden death.||

In hemiplegiac subjects rigidity is observed to be no less strong in the paralysed limbs than in those which were unaffected by the disease. The temperature of the body has been said to influence it. Beclard* speaks of cooling as being always antecedent to rigidity, and Nysten has made a similar statement. But we have had many opportunities of disproving this observation. Ch. Louis noticed the phenomenon in some of the cases just adverted to, while the bodies were quite warm. Its occurrence in cold-blooded animals is, we think, a sufficient refutation of the idea that it bears any necessary relation with the loss of heat. Moreover Devergie has very properly pointed out the inconsistency of this notion with the fact that rigidity appears first upon the trunk, the region which is the last to be deserted by caloric.

The cause of rigidity is referred by most authors to a sort of lingering vital contraction. It is often spoken of as the last effort of life: "Il semble que la vie," says Nysten, "se réfugie en dernier lieu dans ces organes, et y détermine le spasme qui constitue le roideur." † This author not only refers it to contraction, but endeavours to explain how a very low degree of the ordinary kind of contraction may be sufficient to stiffen the muscles though not to move the part with which they are connected. Supposing that a muscular effort equal to 20 would completely bend the elbow, one equal to 10 would semiflex it; one equal to 5 would bend it a quarter of the distance; while a force equal to 1-20th only, would perhaps produce no motion at all, nothing but rigidity! Beclard alleges three causes; the last contraction of muscular fibres, the general cooling of the body, and the coagulation of the fluids. The second of these we have already disposed of. Notwithstanding the high authorities in favour of the opinion that rigidity is caused by a vital contraction, we confess that to us it appears a very untenable position. All muscular contraction in its normal condition alternates with relaxation; and although rigidity might be supposed to bear some analogy to the tonic spasm of tetanus, it differs widely from the latter in one important respect, that when overcome by violence it does not return. When we consider that the continuance of the phenomenon in question is long after the cessation of any vital action; that the *usual* time of its accession is precisely that which we have every reason to consider the most unfavourable for the occurrence of any vital action, viz. when all animal heat is extinct, and when sanguineous congestions in the depending parts of the body prove the capillaries to have lost their contractility; it is difficult to regard the process as of a vital character. The mere fact that the rigidity comes on and remains long after the muscles have ceased to respond to the stimulus of galvanism, reduces the hypothesis to the last degree of improbability. Moreover we should scarcely expect the last act of life to be performed in

* We very recently however observed the phenomenon only an hour and a half after the death of a boy by acute peritonitis.
† Méd. Lég. t. ii. p. 361.
‡ Rech. de Physiol. et Pathol. Chim.
§ Devergie, Dict. de Méd. et Chir. Prat. Art. *Mort.*
|| Rech. Anat. Path. p. 500.

* Anatomie Générale, p. 127.
† Op. cit. §v. art. 3.

the extremities; we should naturally look for it about the trunk, in conformity with the order of disappearance observed by all other vital actions; but as we have stated above, this phenomenon both appears and declines first upon the trunk; in other words, according to the hypothesis, the muscles in this part expire while those of the extremities are still alive. Devergie is puzzled to reconcile the long continuance and intensity of rigidity in cases of asphyxia from carbonic acid, with the fact that this agent is destructive to contractility. We are somewhat surprised that he was not brought, by the mutual opposition of these facts, to consider that rigidity and vital contraction have nothing in common but the tissue in which they are manifested.

The third cause enumerated by Beclard is the coagulation of the blood. This is probably nearer the truth than are the other explanations of the phenomenon; but it would be more correct to say that rigidity and coagulation of the blood are effects of the same causes, viz. coagulation of fibrin. They occur about the same time, and are impeded by the same agents. It has been proved that the muscles are the subjects of the rigidity, that they are contracted, and that their contraction is not of a vital nature. As this change must therefore be either mechanical or chemical, what more probable cause (in the absence of actual demonstration) can be imagined than the coagulation of fibrin in the muscles?

The rigidity occasioned by certain diseases may be mistaken by an unpractised observer for mortal stiffness. This error is most likely to be committed in cases of hysteria, for this affection, not content with imitating almost every other malady, has been often successful in mimicking death itself. Tetanus is instanced by some authors as a disease likely to occasion mistakes of the kind alluded to. This may be true of hysteric tetanus, but not of the idiopathic or of the traumatic species, which have characters too striking to be overlooked by even the most inexperienced. Besides, if the rigidity of any given case, supposed by one to be cadaveric, were by another proved to be tetanic, we are of opinion that the condition of the subject would be not a whit less hopeless, since the case implies that the respiration and circulation are apparently extinct; and when this is the case in tetanus, we may feel quite certain that if the patient is not actually dead, he is quite irrecoverable. Nysten declares that the rigid spasm of disease may be always distinguished from that of death by the circumstance that it precedes the loss of heat in the former case, while in the latter the order of the events is just the reverse. This test holds good in a very large proportion of cases, but must not be implicitly relied upon, because, as we have before observed, corpses not unfrequently retain their caloric for some time after rigidity has commenced. A better criterion is that of overcoming the rigidity by force; if it be cadaveric, the contraction is completely annihilated; if morbid, it will return when the force is withdrawn.

A species of rigidity more likely to be confounded with the cadaveric is that which is sometimes found in the dead body, but which is the product of disease. Of this description is the spasmodic contraction which often continues after death by apoplexy and other cerebral and spinal diseases; and the observation of which is as old as the time of Hippocrates. M. Marc relates the case of a gentleman who went to a theatre apparently in good health, and after the representation was over, was found by his friends sitting in the front of the box, with his head resting upon his hands, and his elbows on the ledge. He had died of apoplexy, and been retained in that position by the tonic spasm of his muscles.* This contraction is unquestionably vital, but it ceases after a few hours, and the flexibility is then succeeded by true cadaveric rigidity. In medico-legal cases it is of the utmost moment to bear this distinction in mind, but it is one that has received much too little attention. Many of the standard works upon forensic medicine are altogether silent upon the subject. Its importance was proved by a case which occurred in France some years ago. The body of a man named Courbon was found in a ditch, with the trunk and limbs in such a relative position as could only have been maintained by the stiffness of the articulations. This stiffness, moreover, must have come on at the very time when the body took the said position, unless it could be imagined that the body had been supported by the alleged murderers until the joints were locked by cadaveric stiffness, a supposition infinitely too improbable to be entertained for an instant. But by regarding the rigidity as of a spasmodic nature (resulting from apoplexy, of which there were sufficient proofs in the necroscopy), the difficulties of the case were altogether removed. A full report of the case, and of the medico-legal consultation upon it, will be found in the seventh volume of the Annales d' Hygiène. In death by asphyxia there is often a spasmodic contraction which may continue for some time after decease. Orfila† is of opinion that this may be readily distinguished by the continuance of animal heat, which he agrees with Nysten in judging to be incompatible with rigidity. While denying the universality of this principle, we think it sufficiently extensive to admit of a very useful application in a great number of instances.

From what has been said, it can scarcely be doubted that rigidity is a certain evidence of death. Prior to this there is no indication derivable from changes in the tissues which can be depended upon; but the flexibility that follows it affords, if possible, still stronger proof of the condition of the body. There is no state with which it can be confounded if we except the interval between spasmodic and true *post-mortem* stiffness; but very little caution is requisite for avoiding a fallacy of this description.

* Annales d' Hygiène, &c. t.vii. p. 604.
† Leçons de Méd. Lég. t. ii. p. 195.

The next remarkable change which takes place in the tissues is putrefaction, a process in which the ultimate elements of the body, operated upon by external causes, enter into combinations incompatible with the existence of those proximate principles of which the textural molecules are compounded. Some physiologists conceive that even putrefaction is not a necessary sign of death. Winslow, however, pronounces it "unicum signum;" and Bruhier expresses a similar opinion. Haller* says that it may commence in a living person, but that death must be very near at hand. He relates of one Vandenhoeck, his bookseller, that when lying in the last stage of a malignant fever, he prophesied his approaching end, and that he grounded his prediction upon his sense of smell. Orfila, one of the greatest authorities upon this subject, considers the commencement of putrefaction a less unequivocal sign than true rigidity; his opinion rests upon the fact that he has known persons completely recovered, notwithtsanding the skin was covered with violet spots, which exhaled an infectious odour.† It is remarkable that so acute an observer should have overlooked what seems a very obvious consideration, viz. that these violet spots being caused by extravasated blood, perhaps in a state of decomposition, afford no indication that putrefaction has begun in the solids. Sphacelus, though consisting in decomposition, need not be confounded with putrefaction. The latter change begins always, according to the observation of M. Devergie, either upon the abdomen or the thorax, and has the appearance of a large diffused patch of a green colour, which afterwards becomes brown. The brown portion is surrounded by a green areola indicating the extension of the process. Into the history of putrefaction we cannot enter, but must refer to the valuable "Exhumations Juridiques" of MM. Orfila and Lesueur, and to some papers by M. Devergie in the second volume of the Ann. d'Hygiène on the changes in the bodies of persons drowned, and also to a controversy upon the latter subject between this author and M. Orfila, in the fifth and sixth volumes of the same work.‡

After the decomposition has advanced to a certain stage, but sometimes without any putrefaction at all, the tissues, instead of being dissipated by conversion into *liquid* and *gaseous* substances, which is the essential part of the putrefactive process, may be converted into *solid* matters widely differing from the original molecules. (See Adipocere and Mummification.)

3. We have lastly to notice a few signs of the reality of death gathered from the external aspect of the body. The appearance of the face has been already described among the signs of the moribund state. We have only to mention in addition, that instead of the paleness or lividity that were present at the time of death, a rosy hue may appear upon the cheeks, which has not unfrequently occasioned a deceitful hope that life was not yet extinct. The cause was very rationally ascribed by Mr. Chevalier to the action of atmospheric air upon the blood accumulated in the capillaries. This phenomenon is more likely to occur when syncope has followed asphyxia. We remember it once very distinctly in a person who had died of acute hepatitis, but in whose last hours there had been considerable pulmonary congestion; it made its appearance on the third day after death. The state of the eyes has been much insisted upon by some; particularly their dulness, the shrinking of the cornea* from the diminution of the aqueous humour, and the viscid mucous secretion which forms what is called the film of death; but these appearances may be absent in real death, and present before life has terminated. Thus the eye is often prominent and glittering after death by carbonic acid, and by hydrocyanic acid.

The iris is generally represented to be in a state of dilatation. Winslow† paid considerable attention to it, and states that he generally found the pupil of a moderate size, often much contracted but never much dilated. Whytt‡ makes the same observation. The fact appears to differ with different animals. Thus in the cat and pigeon the pupil dilates after death, while in the rabbit it contracts.§ Our own observations upon the human subject incline us to report the pupil a few hours after death as in a state midway between contraction and dilatation. It is difficult to speak with precision upon the point, because that which would be relative contraction in the pupil of one person would be dilatation in another, and vice versâ. We have known observers confound immobility with dilatation, and to this circumstance we attribute the common statement that the pupil is dilated at and after death. It is evident that if we admit that the contraction and dilatation depend upon predominant action of the longitudinal or of the circular fibres, we ought to expect in the death of the part neither the one condition nor the other; but as the contractility of this as of other muscular parts may survive the cessation of the central functions, either set of fibres may prevail for a time. It must be remembered however that contraction of the iris may depend upon a cause altogether different from contraction of its fibres, viz. congestion of blood in its tissue, which is said to have some analogy to the erectile. M. Renard states that in some experiments upon dead bodies instituted for the purpose of ascertaining the effects of compression of the diaphragm upwards by the development of gas in the abdomen, found

* Op. et loc. citat.

† Op. cit. t. ii. p. 231.

‡ Devergie's papers are embodied together with more recent observations in the first volume of his "Médecine Légale," published a few months ago.

* Louis fancied that this sign was invariable.

† Op. cit.

‡ On the Vital and other Involuntary Motions of Animals, p. 129.

§ Mayo's Outlines of Physiology, p. 292, 3d edit.

that it occasioned "refoulement vers la tête de la portion fluide du sang qui est contenu dans l'oreillette droite, et par suite, réplétion, tuméfaction des veines du cou, de la face, de l'encéphale, suintement, exsudation séreuse ou sanguinolente par les porosités, les extrémités des réseaux capillaires; quelquefois aussi, par suite de ce reflux dans les réseaux capillaires, *resserrement de la pupille*, réplétion, distension, saillie des yeux, qui étaient d' abord ternes et relâchés, &c. &c."*

M. Villermé† has described an appearance of the hand which he considers characteristic of death. He says that when dissolution has taken place the fingers are brought together and slightly bent, but that the thumb is covered by them, being always found in the hollow of the hand directed towards the root of the little finger. The phalanges of the thumb are extended upon one another, but the first is flexed upon the metacarpal bone. Villermé states that he had often noticed this appearance in dead bodies on fields of battle and in hospitals, but that he had never attached any importance to it as a sign of death, till his attention was directed to its value by M. Breschet. We have often confirmed the truth of Villermé's description by our own observations, particularly in hospital cases, before the bodies have been subjected to the *straightening* processes of the attendants upon the dead. When the appearance has been wanting, we have had reason to suspect that it had been removed by force.

The last sign to be spoken of is the altered colour of the surface, presenting lividities of various extent. They may occur in spots or in circumscribed patches, but more frequently they take the form of an irregular suffusion of a pale violet, or a dull reddish hue. They always occupy the depending parts, and are most intense where the skin hangs loose, as in the scrotum, the penis, and the labia. They have also a direct ratio with the suddenness of the death, the quantity of blood in the system, and its tendency to continue fluid. Their presence indicates that gravitation has either subdued the capillary forces, or has come into play after the cessation of the latter. But they may occur during life. We have often noticed that the livor of the skin in bronchitic affections is more intense in the back and the sides, and is even confined to these parts. There can be no doubt that congestions in the parenchyma of the lungs are often dependent upon position. The questions that arise out of these appearances have more to do with the cause of death than with the reality of this occurrence. When circumscribed, they may be confounded with ecchymoses resulting from violence. To enter upon the discrimination of these conditions would engage us in a discussion far too lengthened for this article, which has already exceeded its limits; we must content ourselves with referring to medico legal treatises and to an extremely valuable paper by Dr. Christison in the Edinburgh Medical and Surgical Journal.*

We shall conclude with a brief abstract of M. Devergie's observations upon the knowledge which we may collect from the state of the body respecting the time which has elapsed since death.

We may suspect that the body has been dead from two to twenty hours if there be flexibility, elasticity, heat, and contractility; from ten hours to three days, if there be rigidity of the joints, pitting of the soft parts, the natural colour of the skin, loss of animal heat, and no contraction under electric stimulus; from three to eight days, if there be flexibility (after rigidity) and no contractility; from five to twelve days, if the soft parts are puffed, elastic, and shining. After the twelfth day there is usually a separation of the epidermis, as well as a green tint of the abdominal integuments.† But no certainty must be attached to these statements; they are merely approximative. The modifying influence of external media upon putrefaction is all but unbounded. In summer as much alteration may take place in five or six hours, as in eight or even fifteen days of winter.

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(J. A. Symonds.)

* Considérations sur l'Ouverture des Cadavres, p. 88.

† Ann. d'Hyg. t. iv. p. 420.

* Vol. xxxi. p. 248. See also an able article upon Pseudo-morbid Appearances by Dr. R. B. Todd in the Cyclopædia of Practical Medicine.

† Op. cit.

ANALYTICAL INDEX

TO THE

FIRST VOLUME.

END OF VOL. I.

MARCHANT, PRINTER, INGRAM-COURT, FENCHURCH-STREET.