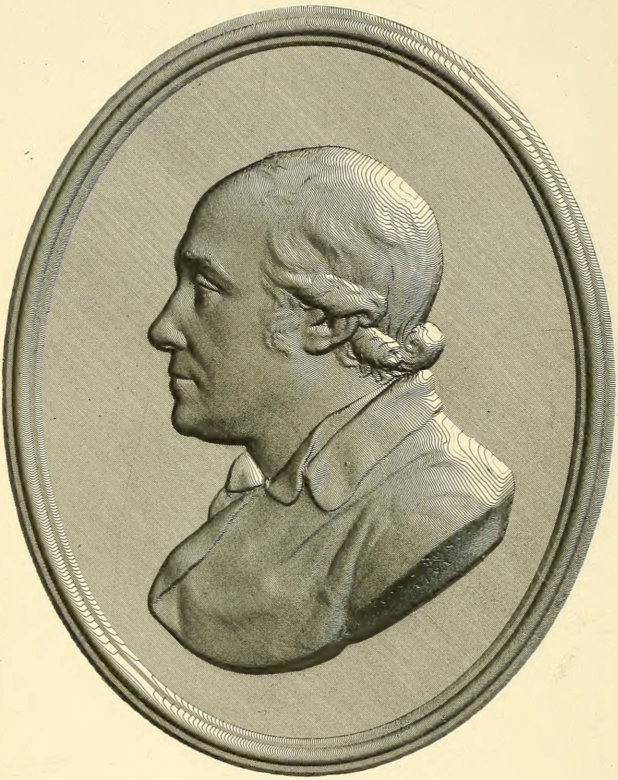

H. Adlard sc.

JOHN HUNTER, F.R.S.

From a Medallion taken in 1791.

London: John Van Voorst, Paternoster Row.

ESSAYS AND OBSERVATIONS

ON

NATURAL HISTORY, ANATOMY, PHYSIOLOGY, PSYCHOLOGY, AND GEOLOGY.

By JOHN HUNTER, F.R.S.;

BEING

HIS POSTHUMOUS PAPERS ON THOSE SUBJECTS,

ARRANGED AND REVISED, WITH NOTES:

TO WHICH ARE ADDED,

THE INTRODUCTORY LECTURES
ON THE HUNTERIAN COLLECTION OF FOSSIL REMAINS,

DELIVERED IN

THE THEATRE OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND,

MARCH 8TH, 10TH, AND 12TH, 1855:

By RICHARD OWEN, F.R.S., D.C.L.,
SUPERINTENDENT OF THE NATURAL HISTORY DEPARTMENTS, BRITISH MUSEUM;
FULLERIAN PROFESSOR OF PHYSIOLOGY IN THE ROYAL INSTITUTION OF GREAT BRITAIN;
FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC.

VOLUME I.

LONDON:
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TO

THE FELLOWS AND MEMBERS

OF THE

ROYAL COLLEGE OF SURGEONS OF ENGLAND,

THIS EDITION

OF HUNTER'S POSTHUMOUS PAPERS,

THE PREPARATION OF WHICH TERMINATES THE EDITOR'S

LABOURS IN MAKING KNOWN THE THOUGHTS AND WORKS OF

THE FOUNDER OF PHILOSOPHICAL SURGERY,

IS RESPECTFULLY DEDICATED.

ADVERTISEMENT.

It was known to some friends of Mr. Clift, F.R.S., Conservator of the Museum of the Royal College of Surgeons, that, during the period between 1793 and 1800, when he had sole charge of the Hunterian Collection and Manuscripts, he had copied some proportion of the latter before they were removed from the Museum in Castle Street, Leicester Square, by the Executor, Sir Everard Home.

Of this fact I first became aware when engaged in preparing the 'Catalogue of the Physiological Series of the Hunterian Collection in the Museum of the Royal College of Surgeons,' having then received from Mr. Clift transcripts of MSS. containing Hunter's schemes of classification of animals according to the Heart, Brain, &c., printed in the third volume of that Catalogue, 1835, as from "the Copy of a Hunterian Manuscript in the possession of Mr. Clift," p. *v*; and, subsequently, copies of Mr. Clift's transcripts of Hunter's "Experiments on the Impregnation of Ewes," "ib. of Sows," and "Observations on the Humble-bee," which are printed in the fifth volume of that Catalogue, 4to. 1840, pp. 38, 131, and 135.

A short time previous to Mr. Clift's decease, he placed in my hands the whole of his transcripts of the Hunterian Manuscripts, with an autograph statement of the important fact; and a 'Note' respecting those MSS. which will be found in the Appendix B, p. 497.

They were much more numerous than I had anticipated, and included copies of most of those MSS. which are specified in Mr. Clift's evidence before the "Medical Committee of the House of Commons" (Appendix B).

After Mr. Clift's decease I proceeded to classify the Subjects of the MSS.; to prepare 'press-copies' of them; to determine the Species of animals therein referred to, and especially of those of which Hunter's 'Notes of Dissection' were thus preserved; to compare the descriptions of structures in those notes with the Preparations in the Hunterian Collection, in order to refer to the preparations of parts of animals which are described in the Anatomical MSS., or which relate to propositions recorded in the Physiological Essays.

Where the number only of the Preparation is given, as at vol. i. p. 20, or where the abbreviation "Phys. Series" is added in the foot-note, it refers to the "Physiological Series of Preparations in Spirits," as numbered in the "Descriptive and Illustrated Catalogue" of that series, 4to, 5 vols. 1833—1840. These Preparations are now (1861) arranged in the galleries of the 'third' museum of the Royal College of Surgeons, Lincoln's Inn Fields. Where Hunterian specimens in other series are referred to, the name of the series or its Catalogue is added, as 'Osteol. Series,' 'Series of Monsters,' 'Dry Preparations,' 'Catal. of Fossils,' &c. The numbers of the Osteological specimens are those by which they are referred to in my "Descriptive Catalogue of the Osteological Series," 4to, 2 vols. 1853: those of the Fossil specimens, as at pp. 314, 317, vol. i., are the numbers in the "Descriptive Catalogue of the Fossils," 4to, 3 vols. 1845, 1854, and 1856.

Explanatory Notes have been sparingly appended. I believed that the Physiologist, Anatomist, or Naturalist might prefer to frame his own explanation of phenomena alluded to, and would be able to make his own comparison of Hunter's views with the present state of science.

The Editor's notes are distinguished from Hunter's by being placed below the line, within brackets, and by having numerals prefixed instead of the usual marks of reference. Those by Mr. Clift are marked by his initials W. C. The parentheses of Hunter are bracketed thus ( ); those of the Editor thus [ ].

Save in the case of grammatical error, or some very obvious omission, which has been supplied in the brackets [ ], I have rarely meddled with the text: it is here and there obscure enough to test the acumen of a skilled logician to decipher the sense. But it is always a matter of interest to endeavour to make out the meaning of a deep and original thinker; and different minds, unbiassed by any suggestion of the Editor, may be induced to give their views of Hunter's meaning, and their opinions of his conclusions. It may be interesting also to some, standing on the vantage ground of seventy years' progress, to know what such a self-taught philosopher did not know on the subjects he grappled with: and a small proportion of the present writings of Hunter may chiefly serve to illustrate his mental peculiarities and shortcomings.

To those who are conversant with Hunter's style, other testimony of the authenticity of the present writings will be superfluous: and it has seemed to the Editor that the requirements of science would be best met by presenting these writings 'pure and simple,' as Hunter left them.

With the exception of the very small proportion, of which the subjects are noted in the 'Table of Contents,' or in 'Appendix B,' they are now for the first time published.

That Mr. Clift had himself contemplated their publication, is probable from the annotations which he had himself appended to his transcripts. These are given, with his name, in the present edition, which is, indeed, the fulfilment of his last wish on the subject.

Mr. Clift's original Copies of the Hunterian Manuscripts have been deposited by me in the "Library of the Royal College of Surgeons," in order that my additions or alterations may be tested, and involuntary omissions or errors corrected.

Some may wish that the world had never known that Hunter thought so differently on some subjects from what they believed, and would have desired, him to think. But he has chosen to leave a record of his thoughts, and, under the circumstances in which that record has come into my hands, I have felt myself bound to add it to the common intellectual property of mankind.

The Portrait of John Hunter, the frontispiece of Vol. I., is from a bronze medallion, executed in 1791, liberally presented to the Editor by Charles Hawkins, Esq., F.R.C.S., Inspector of Anatomy.

The Facsimiles of the Hand-writing of Hunter and Solander, the frontispiece of Vol. II., are from the original Hunterian MS. on the 'Vegetable Economy,' for which the Editor is much indebted to Edward Rushworth, Esq., nephew and executor of the late Capt. Sir Everard Home, Bart., R.N.

CONTENTS.

OBSERVATIONS ON NATURAL HISTORY.

Introduction to Natural History.

Classification of Animals.

OBSERVATIONS ON PHYSIOLOGY.

Of Life and the Living Principle.

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[1] [An extract from this MS. had been prefixed by Hunter to the MS. Catalogue transferred with the Collection to the Museum of the Royal College of Surgeons, and is printed in the Physiological Catalogue, vol. ii. p. 66.]

[2] [Ib. vol. ii. p. 25.]

[3] [Ib. vol. i. p. 77.]

Of the Senses.

[1] [Physiological Catalogue, vol. i. p. 112.]
[2] [Ib. vol. ii. p. 111.]
[3] [Ib. vol. iii. p. 100.]
[4] [Ib. vol. iii. p. 85.]
[5] [Ib. vol. iii. p. 61.]
[6] [Ib. vol. iii. p. 53.]

Page

Observations on Generation.

Progress and Peculiarities of the Chick[1].

[1] [The original MS. accompanied the Hunterian drawings of the development of

the chick, and is preserved with them in the Royal College of Surgeons: it is printed with my notes in the Physiological Catalogue, vol. v.]

OBSERVATIONS ON PSYCHOLOGY.

OBSERVATIONS ON PALÆONTOLOGY.

OBSERVATIONS ON PHYTOLOGY.

A TREATISE ON ANIMALS.

Book I. On the Structure and Composition of Animal Bodies.

FAC-SIMILE OF THE HANDWRITING OF JOHN HUNTER.

It would appear that weakness in any thing that has powers of action within itself, produces or stimulates the parts so weak to take all advantage of collateral support. Even a Bean which when strong, seems to depend intirely upon its own powers yet if it grows weakly, as when not in the sun or any other cause acting to hinder strength when growing In such if a stick is put into the ground close by it, it will twin around it in loose spiral turns

FAC-SIMILE OF THE HANDWRITING OF DR. SOLANDER.

I have made a hasty calculation of these as follows; viz.

Somniferous plants	448
Caule volubili	195
Caule radicans	16
foliis cirrhiferis	107
affected by the touch	6
having self motion	1
	773

ESSAYS AND PAPERS.

OBSERVATIONS ON NATURAL HISTORY.

Introduction to Natural History.

OUR ideas of the first formation of the world, of the production and distinctions of vegetables and animals, and of the alteration which has taken place in the course of time, can only arise from observation on the present state, or from history, of things.

As to History, the Sacred Writings, which are probably some of the earliest, give us an account of the beginning of the world and its productions. But as Moses derives his authority from powers we cannot admit into natural causes and effects, we must leave the first formation of things, and take them up as formed.

However, if we were to take up this subject as it now appears, and apply that to what is past, we should deceive ourselves, for time is continually producing changes.

It must be confessed that in Moses' account of the beginning of the world and its productions there is something classical or scientific; for he divides the labours of the Six Days very naturally. The first two days were employed in the formation of the globe, and everything relating to it. Then on the third day the earth brought forth grass, &c., yielding seed of its own kind. On the fifth day the waters brought forth fish and fowl; and on the sixth day the earth brought forth the beasts of the earth; and last of all Man was formed. Now this is a natural rise or progression from the most imperfect to the most perfect.

Moses has been [more] particular in his account of Man than of any of the other creatures; but, from him, it would appear that only one Man was formed in the supernatural way he describes. Yet, from the history, we are naturally led to suppose that there were more, either produced, or existing at that time, as Cain went to another part of the globe and got him a wife; he was also afraid of being killed by strangers on being turned out.

The same history brings us much nearer, viz. the Flood; where it is positively asserted that every living thing was drowned, except seven of each species that were clean and two of every sort that was unclean*. And likewise that there were but one man, his wife and offspring saved. Later historians have thrown but little light upon this subject, and many have only endeavoured to make the present appearances clash with the account given in the Old Testament.

Man is born or comes into the world ignorant; but he is furnished with the senses, so as to be impressed with the properties of things; by which means he gradually, of himself, acquires a degree of knowledge. But Man goes farther, he has the power of receiving information of things that never impressed his senses: and, if he has that power, it is natural to suppose that one Man has the power of communicating his knowledge of things to another, each giving and receiving reciprocally; which we find to be the case.

And it must also follow, in a connected series, that the mind is capable of connecting signs or types of things with the things themselves, so as to form in the mind a something similar to an impression on the sense to which the sign or type refers, called an 'idea.' If this was not the case, knowledge would never increase.

This of signs, although natural in themselves, yet are arbitrary in their modes, therefore varies[1]: by which means, knowledge is in some degree preserved, and by which means it increases; which leads the mind on further and further; and which, as it were, leads the mind into the study of natural things. Therefore, the study of Natural History is an effect of considerable advancement in civilization and in the cultivation and improvement of natural things; and, therefore, the study is posterior to those advancements.

Men, at first, hardly considering those things which were the cause of their sensations, therefore were guided by instinctive principles, and a kind of habit arising out of practice; for civilization, cultivation, and improvement took place at first by slow and almost imperceptible

* The idea affixed to clean and unclean were those that were eatable and those that were not eatable.

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[1] [The following is an attempt to make the meaning clearer in the above characteristic example of Hunter's occasional obscurity:—

"This [subject or system] of signs, [which signs] although natural in themselves, yet are arbitrary in their modes, therefore varies." Although why an unvarying (system of spoken or written) signs of ideas, might not have served as well as a varying one, for the preservation and transmission of knowledge, is not very apparent].

degrees. Men, then, hardly considering what they did know, because perhaps they knew but little in proportion to what they saw, the transition from one improvement to another was gradual; whereby they almost lost sight of the past by its having become familiar to them; and they had not the means nor the disposition to record it farther than by narration, which is called 'Tradition.'

As cultivation makes considerable changes and improvements in natural things, and as, from the above reasons, we are in a great degree ignorant both of those improvements and their cause, it becomes difficult to know what these improvements are and to account for the causes of many appearances now existing, or to know with any degree of certainty what [natural things] were original and what are still original, viz. what has not undergone any change from cultivation and what has. For it is evident by classing nature, and so by bringing things into their ultimate class, viz. species, that there is in a great number of species a considerable variety in the same: and, from this variety in the same species, it becomes a doubt whether they were all original, or whether any one of them are original, or none of them; or, if any one be original, which that one is.

But those improvements, &c. in natural productions can only take place in vegetable and animal matter, those being the only matter that has the power of reproducing itself. For the common mass of earth appears to have no power of reproduction, therefore no permanent principle of variation: for, when parts of the mass do vary, it is from some immediate cause as a mixture of different substances, &c., which terminates with itself and therefore may be called accidental.

If the study of Natural History had been coeval with its own advancement, and had that advancement been communicated to the world, as it arose, for the improvement of mankind[1], we should not now be at a loss to account for many appearances that owe their birth to changes that have taken place in the productions of Nature by Time, of which we are at present ignorant. But, as the advancement in knowledge had gone considerable lengths before the certain means of communicating it was known, as also what may be called a permanent mode of communication,—and as, where those means were known yet a disposition [to use them] was wanting, [there being] besides, a degree of superstition and a bias for the marvellous, which is always introduced with ignorance,—it is no wonder we are left in the ignorant state we are in at present.

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[1] [If the study of Nature had been coeval with the changes in Nature, and those changes had been recorded as they arose, &c.]

Therefore, to make up the loss as much as possible, it is incumbent on us to go as far back as our knowledge directs us; to compare those [states of things] with great care and accuracy with the present; and to mark down what state things are now in; [in order] that future ages may be able to account for what we are now ignorant of. For, by their being acquainted with what has happened within the History of Natural Things, the state that things were in prior to such inquiries—those changes prior to the present—may be hereafter tolerably well accounted for.

To attempt to trace any natural production to its origin, or its first production, is ridiculous; for it goes back to that period, if ever such existed, of which we can form no idea, viz. the beginning of time. But, I think, we have reason to suppose there was a period in time in which every species of natural production was the same; there then being no variety in any species; but the variations taking place on the surface of the earth, such as the earth and water changing situations, which is obvious; as also the change in the poles or ecliptic, which I think is also obvious. The varieties [so produced] are but few and are still existing in what may be called the 'Natural' Animal. Also civilization has made varieties in many species, and without number, which are the 'Domesticated.'

In the study of any science, the principles of which are not universally known or understood, it becomes not only necessary to teach the science itself or what its principles are, but it is always necessary to say what it is not; for, from a want of a sufficient knowledge of the subject, many sciences have been blended with one another so as to unite them where they had no connexions, and thus [they have been] falsely made to appear to belong to each other: by which means it was difficult to say where one principle began and another ended, or that there was any one principle inseparable from another.

The most familiar or most known is commonly used to explain the most unintelligible. Thus, for instance, Mechanics were introduced to explain the effects produced by Chemistry, and both Mechanics and Chemistry (which last was partly explained by Mechanics) have been introduced as the cause of many of the operations both of the Vegetable and Animal productions, in which they have not the least share.

In the Natural History of Vegetables and Animals, therefore, it will be necessary to go back to the first or common matter of this globe, and give its general properties; then see how far these properties are introduced into the vegetable and animal operations; or rather, perhaps, how far they are of use or subservient to their actions.

All matters, of whatever kind, have properties common to them all, by which they are called 'Matter,' as Solidity, Fluidity, Vapour, Form, Weight, so as to become the immediate object of the senses: but all Matter has properties abstracted from those which may be called the specific properties by which one species of matter is distinguished from that of another—the knowledge of which arises from investigation; which [properties] may be called 'secondary,' some having one, two, or more secondary properties, others having others, all having some, and many of these secondary properties being more confined, not being common to all matter. It is therefore 'secondary properties' that in some degree distinguish one kind of matter from another. Two solid bodies may have the same solidity, form, weight, &c., yet [consist of] a very different species of matter from each other—for instance, crystal and calcareous earth may have the above properties in common with each other, yet differ very much from one another in many other properties.

When they are to undergo some change, one will not be affected by any acid, while the other is totally dissolved, which becomes one distinguishing mark between these two substances or species of matter. But, although dissolving in an acid is one characteristic of calcareous earth, yet it must have others to distinguish it from other earths that have the same property of solution in an acid. Magnesia [*e.g.* so resembles calcareous earth], but its forming a selenite with the vitriolic acid makes a distinction. But, perhaps, the true character of calcareous earth is, its affinity to animal and vegetable substances, when simple; although this last property is not peculiar to this earth, for alkalies are endowed with the same. Alkalies have properties that the calcareous earths have not, by which they are distinguished from one another. So that its forming a selenite with the vitriolic acid and its reunion with the vegetable and animal substances become its specific property, while its solution in an acid in general was only its specific property in the second degree.

The same observation holds good respecting fluids: for two fluids may have the same fluidity, specific gravity, &c., yet be very different in their other specific qualities. Water is a fluid, so is oil of turpentine, spirits of wine, &c., but their specific properties are very different.

Many earths are vitrifiable, others not; however, such as are vitrifiable have other properties by which they are better known than by their vitrifaction or not—by which they are distinguished—the vitrifaction being only considered as a collateral property.

Is it possible for an absolute existence to be mutable, or in other words, is anything that is really existing changeable? I should be inclined to believe that whatever does exist or can exist is not changeable.

Of Matter.

In the investigation of Matter it may be a question whether the thing impressing or the thing impressed, ought to be considered first, being in themselves coeval or necessarily depending on each other ; but, as the thing impressed appears to itself to be passive, and as it receives intelligence of the impressor, it is naturally, from cause and effect, led to the thing impressing ; and, when it considers itself, it is an abstract consideration. And, in this investigation, we are to consider ourselves as matter, because we have within ourselves the power of impressing either ourselves or others ; therefore, ourselves appear to ourselves to be matter as much as anything else that we call matter.

By matter, then, we mean everything that is capable of making such impression as to give us some sensation, or, everything that is capable of affecting by some means or other our senses. This globe, with all its attendants and modes of action, comprehends every material fit to produce such effects.

The universe has been divided into 'Matter' and 'Spirit;' but, admitting the possibility of such a thing as 'spirit,' we cannot possibly have an idea of it, as it goes beyond matter ; beyond which we cannot go even in idea*.

Matter is endowed with properties which become the cause of our sensations ; for it is only the properties in common matter and our impressions combined that produce sensations, or the knowledge of matter at all. Therefore, without sensation, no knowledge of matter would have existed ; and, without matter, no sensation could have existed ; therefore matter and our senses perfectly correspond. But our senses, simply, do not give us an exact idea of the immediate impression ; in many [instances they give us] a reference only to something else, to that which becomes the immediate use or application of such impression ; and that is owing to the mode of immediate impression being invisible in itself, or being incapable of affecting in this action any other sense, and therefore is referred to another cause.

* This world has been divided into 'Matter' and 'Spirit.' Matter abstracted from proportion could only just strike our senses ; but there were properties that could, in idea, be abstracted from Matter, which [abstractions] were called 'Spirit.' Spirit was a something superadded to, and therefore distinct from, matter ; but a more just idea of these two is to suppose that 'Spirit' is only a property of 'Matter'[1].

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[1] [This is an instance of one of those 'Notes' in which Hunter endeavours to make more intelligible, some idea the expression of which he found difficult or oppressive.]

Touch is probably the only sense that is cognizable by another sense besides the immediate sensation; and, indeed, taste may be supposed to be the same; but taste certainly goes a step further.

If we see a body in motion before us, we are [led] from the habit of combining this motion and the impression of its touching us, to act accordingly, either by avoiding, meeting, &c.; so that these two become the great cause and guide of most of our actions: but all this is no more than what is, probably, common to all animals endowed with such senses [as ours]. Therefore Man goes further into the cause of sensation: finding that sight only helps out touch, but touch not sight, he inquires how sight is produced. The same in [regard to] sound: for, although touch remotely and sight immediately help us to the remote cause of sound, yet not to the immediate cause of the sensation. The same [may be said] of smell and taste.

Man is not satisfied with the modes only of immediate impression, or with the combination of sensation simply in the mind; but he goes into the investigation of such masses of matter as produce these effects, comparing them with each other, and [investigating] the common properties of each as a whole, which gives us the principle of what is called 'Experimental Philosophy.' Thus he considers solidity, fluidity, and vapour, the difference in the attractions called weight, with all the different properties of which it is composed. He then applies these different properties to different purposes, which constitutes 'Mechanics;' but that is taking matter only in the gross. But he takes any one species of matter, separates it, and considers it abstracted from our sensations; and finds that it is, or may be, composed of a variety of such matters as strike our different senses in common; and then we say that such is composed of such other species of matter, and we again combine or unite.

Observation carries him still further; for he finds effects that are not cognizable by any of our senses: therefore he reasons from analogy, as in the case of that [ideal] substance [concerned in reducing] the calx of metals to the metallic form, commonly called 'Phlogiston.'

He even goes further, for he forms in the mind abstract data to reason upon, which is the groundwork of 'Metaphysics.'

Matter being endowed with properties which become the cause of our sensations, and the modes of action of those properties being hardly known, these properties become the foundation of the idea of spirit, viz. a species of intelligent quality that presides over and directs the actions of matter. But, as causes and effects of matter seem to be entirely connected with matter itself, and to be a property inherent in and inseparable from it, and as these are becoming better known, the 'presiding spirits' are every day vanishing, and their authority becoming less[1].

Although 'spirit' is a good deal exploded from having a share in the actions of common matter, yet it is still retained in animal matter; and, most probably, because the action of animal matter is much more extensive and has two states,—the living and the dead: and, as there is no difference in the visible mechanism between the two states, it was natural to suppose that there was what is called an animating or living spirit.

But matter can have some of its properties changed by very trifling circumstances. A piece of glass is transparent; but, if that piece of glass be split, it will become less so; split it into three, still less so; and so on till it becomes the most opaque body that can be: and still the whole is composed of transparent glass: therefore, opacity in a whole does not give the least idea of the transparency of its parts.

The first and great property of matter is what is called its 'vis inertiæ' or resistance, which produces or is the cause of many of the mechanical effects of matter; but the effect of this property is increased by another property in matter, viz. solidity.

Matter is naturally in a solid form, or its parts are united and kept together by a property called the attraction of cohesion. The effect [of this property] increases its resistance, because a greater quantity of matter is brought in to act upon impulse, viz. all that matter that is so connected.

Resistance of matter is as the power of union by the attraction of cohesion and the quantity of matter so united, making one whole, called a solid body; but, if divided into small parts which are only in contact, so as to easily move upon one another, as gravel, &c., then the resistance is as the quantity that is made to move and the friction of the moving parts upon one another.

Matter in a solid form admits of every possible shape, the attraction of cohesion of each part being stronger than the attraction of the whole to its own centre, and which may be called centripetal attraction, or stronger than the attraction of its parts to the earth. From external shape, joined with sufficient solidity, arise many properties, when matter is opposed to matter; which becomes the cause of all the mechanical effects of matter.

But matter can have its attraction of cohesion destroyed, so that its parts can be made to move upon one another, when it is called a fluid: then it has only the attraction of fluidity. The resistance of the fluidity

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[1] The dominant idea of the 'Philosophie Positive' of Comte.

of bodies bears some proportion to the resistance of the same bodies in a solid form—*e. g.* the resistance of melted lead to that of water bears some proportion to what solid lead bears to that of ice.

Although matter in general may be rendered fluid, yet it is an unnatural state, and requires other properties in matter to effect it. But, in some, it is so easily effected, that the common operations in the general system are in most parts capable of effecting it; therefore we have that substance, called water, preserved in that state almost everywhere on the globe, or easily rendered so by art.

Fusion implies solidity. If an impalpable powder is fused it will form a solid when cold; therefore, when quick lime is so heated as to take on the properties of a fluid, yet it cannot be considered as such, because it does not become a solid on cooling, but remains a powder as before.

Vapour is another state of matter where both the attraction of cohesion and the centripetal is destroyed. [It is a state dependent on a force] which may be called centrifugal or repulsive; but most probably is not [due to] a property inherent in the matter itself, but [to its] being joined with matter which has this power in a great degree, as fire. The resistance of vapour is as the quantity of matter in a given space, perhaps bearing no proportion to the solid form of the same matter; *e. g.* perhaps the vapour of mercury may make as little resistance as that of water. Matter being thrown into vapour is only an increase of the power which produced fluidity, so that the same principle which produces the one effects the other.

All matter may be reduced to such small parts as to float in any medium; for their cohesion to that medium may be increased so as to destroy the power of gravity.

Does solidity depend upon there being no matter situated between the particles of matter, such as water, air, or heat?

We may observe that in Natural Things nothing stands alone; that everything in Nature has a relation to or connexion with some other natural production or productions; and that each is composed of parts common to most others but differently arranged. Therefore, in every natural production there is an appearance of affinity in some of the parts of its composition [with those of another natural production]; and where there are the greatest number of these affinities or [corresponding] parts, as also the closer the correspondence or affinity between those of one production with those of another, the nearer are those [natural productions] allied[1].

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[1] [The principle of 'unity of plan' and of 'homologous parts' is here ex-

This is not only in the arrangement of the different species of common matter, but also in the arrangements of the same species of matter, which constitute the classing of vegetable and animal matter. Therefore, almost every subject appears to be composed of parts of a great variety of other subjects; and, as each part of which it is composed not only belongs to one but to a great variety of other subjects, every part of any subject becomes classible with those various subjects to which it belongs. This might be illustrated by anything in Nature. Every property in man is similar to some property, either in another animal, or probably in a vegetable, or even in inanimate matter. Thereby [man] becomes classible with those in some of his parts. But if one whole was in possession of a single part of every other, then it would be impossible to class it. But there is no whole but possesses several properties that are peculiar to some others; by which means wholes can be classed with each other. Thus the four-stomached animals have somewhat similar teeth and cloven feet. But as these [resemblances] spin out *ad infinitum*, the subject of classing, instead of bringing things together that have a connexion, for the easement of the mind, would complicate [the matter] so much as in the end to be unintelligible. Therefore, in classing of things, it is only the great distinguishing parts that should be arranged. Mankind are classible into sizes, but it would be very absurd to be very nice in this class.

Nature, in her first formation of bodies, seems to have been particularly careful of forms, establishing a principle of formation in every distinct class of beings, whether Mineral, Vegetable or Animal[1]; which principle becomes their future guide from which every mechanical property arises. In common matter we have the different crystallizations, which seems to be the most simple [principle of form] of any; as it arises entirely from the nature of the matter of which they [the crystals] are composed; [as, *e. g.*] simply earth, each earth producing a crystal of its own kind; or, if compounded, then a crystal according to the compound. But, in vegetables and animals the principles of formation do not appear to arise from the same cause; although it might with more propriety be supposed [to be so] in the vegetable than the animal; and therefore the different classes of vegetable might be supposed to

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pressed; as well as its application to classification, which Cuvier enumerated in the following axiom: "Deux espèces quelconques d'êtres organisés ont nécessairement quelques points d'organisation par lesquels elles se ressemblent. Ces points d'organisation sont ce qu'on nomme leurs *rapports naturels.* Plus ils sont nombreux, plus ces *rapports* sont *grands.*—Tableau Elémentaire de l'Histoire Naturelle des Animaux, p. 15, 8vo, 1798 (An. 6).]

[1] [The principle of 'morphology' of modern naturalists.]

arise from this cause [viz. the nature of the constituent material]. But I rather suspect that the true matter of which a vegetable is composed is the same in all vegetables, and that the difference in the properties extracted from them when dead, as gums of different kinds, as also resins, are no more than so many secretions from them, formed when alive, as we find in animals.

When those forms correspond with other properties in the body, then they prove one another to be more nearly allied. If a certain shape of spar denotes it to be calcareous, and if [it be] found calcareous upon analysis, then there is a correspondency of properties. Chemistry detects this analogy; because it is only finding out first properties of matter, or separating the first principles from one another, and then saying what might be its properties in a solid form or when it formed a complete body from its compound: but there it leaves us, giving us no analogical assistance in either vegetables or animals; because the component parts of either prove nothing in the compound, as they do in common matter. We cannot say from the analysis of vegetable or animal matter, what [may be the] kind of vegetable or animal such matter belongs to: there we must have recourse to another mode of investigation.

The reason why a vegetable of any particular kind is not detectible by chemistry, is because vegetables are peculiar arrangements of the same matter, viz. matter of one kind in all, and are all reducible therefore to the same kind by analysis.

In animals we must observe the natural operations of the animal; and, where opportunity does not serve us to observe Nature in her operations, we must put her in the way of [yielding the means of] observing those natural processes[1]. We were probably led to the distinct sexes of Plants analogically; they being found out in this way in the Date Palm; and much in the same way we are led to the distinct sexes in Animals.

It is from this universal principle that different arrangements of the productions of the earth have been formed; and it is the observing these affinities and distinctions that constitutes the greater part of Natural History; forming it into a science, beginning with combinations of the most distant affinity and also the fewest in number, and gradually combining nearer affinities as [knowledge of the] connexions may arise, fixing appellations to each [combination or group] for the further benefit of mankind. In vegetables and animals such [groups]

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[1] [That is by physiological experiments, in the devising and performing of which Hunter was pre-eminent.]

have been distinguished by the terms Class, Genus, Species, and varieties of the Species. The first and third are easily distinguished from each other, as they are at the greatest actual distance; but it is often difficult to distinguish between the second and third; as also of the third itself, whether it be a variety of the Species or only belonging to the Genus.

This is like the gradations of shade, the two extremes having the least affinity: but it may not in all cases be so clear how far the two last in affinity are in all their parts really distinct; that is, it may not be clear what is a distinct Species of any Genus, they being so nearly allied in their affinities both in appearance and number.

By Species I believe we now mean, things that have the same relationship in their most essential properties, however they may differ in others. Animals breeding in the full extent of that process constitute the species, although they may differ in some of their parts or other circumstances; but which [differences] are less essential, only constituting a variety. These varieties in the same species are much greater in the domesticated animals than in those that are wild; and this appears to arise from the unnatural life the domestic animals lead, giving changes to the constitution so as to affect propagation. Another cause for it will also be, the preservation of, and the endeavour to propagate, any accidental variety that may take place [in the domestic animal] which might be lost in the wild, or at least not cultivated by human industry, this seldom being in man's power.

Of Animal Matter.

Every thing in Nature is directly classible, and as most things bear a relation to some other, such relationships are also classible, and that according to their nearness.

'Species' is the immediate or direct and ultimate class, and is the common term for anything that appears to be indivisible or immutable (it is here to be observed that I do not mean simply species of matter); but which may vary in a number of other properties, such as being either simple or compound. If it be simply matter, then it is strictly a species of matter, and cannot in itself vary but when making one part of a compound: and, if it be a compound, then it is a property of that compound arising out of the combination that forms the species; and, if decomposed, it is no longer that species of compound, but may form many. A simple species of matter we are probably not acquainted with; but many species arising from combination we are well acquainted with, as water, acids, alkali, &c.; and we know the species arising from their being further compounded; such as forming a neutral salt, which becomes a species from its peculiar properties.

A watch is a species of instrument for dividing time, whatever materials it may be composed of; and though a watch is indivisible, yet it has relationships, such as to a clock or a dial. The relations according to their affinity are also to be classed, which constitutes a genus; therefore we have to every species a genus. A 'divider of time' is a genus, and genera form tribes, &c. Perhaps colours would illustrate this doctrine as well as any subject. There are three primitive colours, and by uniting these by equal proportions they appear to give fresh primitive colours, but which arise from the combination; and by mixing them in various proportions all the varieties of colours are produced.

If we consider the vast extent of properties arising from the various combinations of ten numbers, or the immense variety of ideas expressed by twenty-four letters, we must see that very few primitives may produce a vast variety of properties arising from their various combinations. Although all these divisions are not applied to matter in common, yet they are as proper for matter at large as for those substances to which they are applied.

Animal matter is what I should call a species; not as matter simply, because it is probably the greatest compound we have, but from its properties as a combination. The genus may comprehend only the vegetable and animal [species of matter].

In my Lectures on Surgery I began with distinguishing the difference between vegetable matter and animal matter, and also the matter of the globe; saying, that common matter had undergone a very considerable change in producing the vegetable and the animal, in which was not to be found a particle of any species of common matter, therefore an entire new arrangement or combination of common matter; but that they had sprung from common matter, were supported by it, and returned to it again.

This was with a view to make our distinctions in the actions of the body more accurate; distinguishing with more precision between the actions of animals, the decompositions and combinations of common matter which are chemical, and the operation of combinations of common matter on each other, which is mechanical. Also to show that the vegetable and animal had powers and modes of action totally different from those of common matter, either in its chemical or mechanical operations, and which depended upon their combination with the living principle; the whole operations of Nature appearing thus to consist of a chain of four links.

I observed that animals were formed from and supported by vegetable and animal matter; that the vegetable was formed from and supported by the matter of the globe, as a medium between the globe itself and the animals; for without the vegetable the land animal could not exist. But, in the waters, more especially the sea, the more inferior orders of animals are the support of the more perfect, answering to the vegetables on land; and being well adapted to that office, the more perfect [sea-animals] being larger and fewer in number: and, as water alone appeared to be capable of supporting a vegetable, I observed, that water was the intermediate medium between earth and vegetable. There is great reason to suppose that water may be converted immediately into animal matter by the animal, and that air is only necessary for the completion of animal matter, let it be formed from whatever materials; therefore air is not necessary simply as nourishment, yet may be added to it to complete it.

As water appears to be capable of supporting both the vegetable and the animal, but more particularly the vegetable, but the animal ultimately through the vegetable, it must be supposed to be as great a compound as any substance whatever that has no water in its composition; yet, to appearance, water is the simplest; but it must be of itself a compound of every species of matter into which we find it capable of being converted. And, a vegetable or an animal being formed out of it, proves it. For, there must be in water all the materials for forming either a vegetable or an animal body; and, [in its relation] as nourishment to either, it can only be deficient in quantity, not quality.

How far it is possible to make experiments that would prove it impossible that anything else could go into the composition of a vegetable or animal save water, I will not at present determine. If water [is such] a compound, then Chemistry, we might suppose, could be so applied as to produce out of it all the different substances we find in either vegetable or animal matter; but I should be inclinable to imagine that the same variety of species of matter, when combined in one way, would give a very different result when combined in another; and vegetables and animals formed from water would give very different results from chemical analysis.

The late experiments in Chemistry have gone far to analyse water, even to form it; for, from Mr. Cavendish's experiment, it would appear to be composed of common and inflammable air, the proportion of common to that of inflammable being as one to two and one-fourth*.

These combinations of matter form species having specific names given them, as Wood, Brass, Clay, &c., to which nothing can be added

* Phil. Trans. vol. lxxiv. part 1, p. 119, 1784. [which shows that this MS. was written within ten years of Hunter's death.]

but what goes naturally into the composition, to make them more perfect as a species of matter; for, if it [the body not naturally a constituent] united with the combination, it would then alter the species.

Solution comes the nearest to this idea; it is a union of two species to make a third; and, however compounded [the species of matter may be], yet they unite as two species; which is either by solution or fusion. But all bodies will not fuse and mix, they must have a relation; perhaps such only [will fuse or mix] as constitute a genus.

Thus, if we make salts a genus, two species will mix and retain the general property of salt. If we make metals a genus, they mix or fuse, retaining the property of a metal. But species of two different tribes will not fuse, excepting to produce a very different compound, such as glass; and this requires much more violence than the union of two species of the same genus.

Glass by this means becomes a species, although we know it to be made up of several species. Therefore, in any species of matter, although compounded of a variety of different species which were themselves compounded, the compound from a new combination may become a distinct species. There cannot be in the species of glass now formed a single part as a species of any of the species of which it is composed. For instance, neither calcareous earth, clay, or fixed alkali is to be found [as such] in glass; they are all decomposed [and the characters lost] on which their species depended. Nor is calcareous earth, clay, iron, or volatile alkali to be found in animal matter, till after this is decomposed, and they then have combined as such; therefore such is not in animal matter. A piece of animal matter is wholly dissolvable in a caustic alkali; but, if that animal substance is analysed, parts of it will not dissolve; or, if allowed to putrify, parts of it will not dissolve; therefore it is its combinations that give it the properties of solution. Sulphur is not soluble in water; but it becomes so when compounded with an alkali. Oil the same.

A block of marble gives us a figure when cut out; but we cannot find a figure till cut out: the figure arose from the hand of the statuary. Calcareous earth, therefore, is not in animal matter; but it can be decomposed out of it, which shows calcareous earth to be a compound; nor is calcareous earth or clay to be found [as such] in glass. However, we have bodies compounded of different species of matter, as above defined, mechanically mixed, having a specific name to be known by, such as *bone*. A bone is composed of two species of matter—calcareous earth and animal matter. Therefore a bone is not a species of combination of matter, but is composed of two [such species].

Animals and Vegetables, Comparison between.

It is a common observation that there is a gradual change from the most perfect to the most imperfect animal. Man is given as the most perfect; but which is the most imperfect is hard to say. They have carried this still further, and say the change is continued into the vegetable; but they are not determined where the animal ends and where the vegetable begins. However, if there be any justness in the observations, I should imagine that this might be determined by careful observation to find out absolute principles peculiar to each; for, in the Animal Kingdom, each distinction differs sufficiently from that nearest to it to determine to which it belongs, and the same thing with regard to the Vegetable Kingdom: so that if the change be equal, it will be easy to fix on the animal and on the vegetable. To clear up this point, it will first be necessary to give a true and absolute definition of an animal.

One great difference between the animal and the vegetable is in the mode of digestion. In the animal the food is digested or animalized in the stomach, and afterwards absorbed and taken into the common mass of juices. This is the great use of the stomach, viz. to animalize all digestible substances for the future nourishment of the animal.

What other changes, processes, additions, or reductions it may afterwards undergo in the lungs, is, I believe, not yet known. But whatever it be, it sets out from that point to all parts of the body; as the vegetable juices set out from the roots, &c. to all parts of the plant. But the difference between these two is, that, in the animal the juices are first animalized, and become a moving part of the body, while the vegetable juices are to be considered as no part of the vegetable. In the vegetable the [nutritive] juices are taken in unaltered, and are propelled through the canals of the plant to all the different parts, similar to the [movement of the] blood; but whether they undergo any change in this passage is not, I believe, as yet known.

However, this juice must be changed somewhere; it must be vegetalized before it can become a part of a plant. The question, therefore, will be, whether this juice is changed in its passage through the canals of the plant, so as to be really vegetalized before it arrives at its place of destination? Or, whether it passes on, in its mineral form, to its place of destination, and is only changed there? Whichever way it is, there must always be a change at the place of destination, for there the different parts are formed from these juices, whatever they are, and therefore a second change must take place.

The circumstance of engrafting or inoculating would make us, at first sight, suspect that the juices are changed in the part to which they are ultimately destined; for whatever the part is that is engrafted, it always continues to be of the same kind; so that it might be supposed that the juices came to the part crude and unchanged in the part, and formed the addition just as they were changed. But I am apt to believe that there is a strict analogy between the animal and the vegetable; for although the vegetable has no stomach to vegetalize the food of the plant, yet I look upon the vegetable to be in every part 'stomach,' and that it vegetalizes all the absorbed juices admitting of such alteration; that the juice goes on to the parts of destination vegetalized, as the blood goes on animalized; and that, there, each juice changes according to the nature of the part to which it is assimilated, and according to the action of the parts in which it circulates, and the parts to be formed. In the animal it forms skin, muscle, bones, tendon, ligaments, brain, &c. In the vegetable it forms wood, bark, leaves, flowers, fruits, &c.

Vegetables which have only water to convert into their own substance are always the best; therefore it is reasonable to suppose that water[1] is more capable of being perfectly altered into vegetable matter than any other, and a certain quantity is only necessary; for, when there is too much, it is not so perfectly decomposed as to give all the distinguishing marks of the plant, nor is the plant itself so fine; its growth becomes luxuriant, but its matter not so good.

The stem, tendril, and footstalk of the vine have a vast number of spiral threads running through their substance in the direction of these parts. The sensitive plant has the same kind of spiral threads, but not so many. The way to know the above is to break the plant more than half-way through and bend the remainder, and they may be seen passing between the broken parts.

Animals and vegetables have two different irritations; one is internal, arising from circumstances within the machine; the other is the property of being affected by external stimuli.

Vegetables have a degree of sympathy; for, if a branch is cut off, the whole plant suffers; and this much more in some than in others; therefore gardeners say that such a tree cannot bear the knife[2].

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[1] [Water alone is insufficient; it must contain atmospheric air in solution, and there must be access of carbon to the plant; that which the water contains in solution and which is derived from decaying vegetable and animal substances, is peculiarly adapted to nourish the plant, and constitutes fertility of soil. Salts, earths, even silica, are held in solution and thus taken into the system of the plant to be there disposed of. The superfluous water is exhaled from the pores or *stomata* of the leaves, the oxygen of the carbonic acid is, during daylight, evolved, and the chief materials of the plant are detained, freed from the impurities with which it was blended when absorbed by the roots.]

[2] [The circulation in *Chelidonium*, observable in the vessels containing the milky

Vegetation appears to be the easiest transition from common matter; for it is supported by common matter, or it has a power of converting common matter into its own kind. Animal matter appears to be a second remove from common matter; for it cannot be continued or supported by common matter, therefore it is obliged principally to the vegetable; however, it is often dependent upon itself [or matter of its own kind for nourishment]. But these last [or the carnivorous animals] are few in comparison to the others, and without the other resource animals would annihilate themselves. Let us reckon the whole animal creation as three; two parts of the animals live upon vegetables, and the third of the animals live upon the two other parts: in this way the three are still preserved.

Of the Similarity of the Vegetable to the Animal in the Circumstance of Engrafting.

Animals and vegetables in this respect are exactly similar. For example, a part of an animal is engrafted upon another; that part does not in the least partake of the part of the animal it is engrafted upon, but keeps the original disposition and continues to grow exactly as it would have grown if it had not been removed from its original stock. The same thing attends a vegetable.

In many things animals differ from vegetables; viz. a part of an animal is truly a part, but the part of a vegetable is a whole; for every part of a vegetable in general is a whole; therefore a vegetable that is engrafted, not only continues to grow in the same manner that it would have done, if it had never been removed, but is a perfect tree. It not only forms its own leaves after its own kind, flowers of its own kind, fruit after its own kind, but it is also capable of producing seed, which completes the tree. In the last [property] it differs from all those animals which produce their young from seed.

As a vegetable is a perfect plant in every point, every point is capable of producing what the whole is capable of producing; but this is not the case with an animal. An animal is a compound of parts totally different in their sensations, stimuli, powers, and uses, from one another; each part doing one office and no more, and all obliged to one source for support and sensation. Their specific stimulus [is] within themselves; or their specific stimuli, and the powers and operations arising therefrom, are [severally] within themselves, having no connexion with any [other] part of the body; therefore [a part is]

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fluid, ceases the moment that the plant has received an injury; and is more active in proportion as the temperature of the atmosphere is higher.]

rendered useless when separated. If all these parts had not been made distinct, but had been blended through the whole animal, so that every part formed a compound of the whole, *e. g.*, if every part formed bile, every part formed urine and secreted seed, &c., then each part of an animal would become a whole; so that, when any part was removed, it might be considered as a perfect animal. This is, in fact, the case with many animals[1], but in other respects they are different from vegetables.

As most animals have parts allotted for every purpose, [each] to answer its purpose and no other, the testicles and ovaria then answer the purpose of generation and no other purpose. They are parts whose actions are independent of all other parts of the body; only [they are] obliged to the circulation for supplies, and to the nerves for powers of action. But their particular actions depend upon themselves; therefore, the testicles and ovaria produce the distinct species independent of the whole.

To illustrate this with a supposed experiment: let us take a testicle from a cock and put it into the belly of a gander. If it was possible that the ducts could unite so as to carry the seed that was secreted in that testicle to the female, the produce would be the same as if a cock had trod a goose; so that the powers of the testicle would remain the same as if they had never been transplanted, and would continue to secrete the same kind of semen. The inclinations of the gander would not be towards the hen but towards a goose; for, although the testicles are the cause of the inclination, yet they do not direct these inclinations: these inclinations become an operation of the mind, after the mind is once stimulated by the testicle.

Vegetable and animal life are very similar. They are both capable of being engrafted by parts that are similar to themselves. Whether an animal could be engrafted upon a vegetable, or a vegetable upon an animal part, is not yet known[2].

Similarity in the Propagation of the Species between some Animals and some Vegetables.

Vegetables are not only similar to all animals in the circumstance of simple life, but are similar, in the propagation of their species, to some

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[1] [The infusory and other *Protozoa*; the hydra polype and other *Hydrozoa*, &c. Hunter's previous propositions will be understood to refer to the more conspicuous and higher animals, constituting the ordinary idea of the class.]

[2] [The parasitic growth of certain cryptogamic plants (e. g. *Sphæria*) in and upon the larvæ of certain insects, giving rise to the combination called in New Zealand the 'tree-caterpillar,' would be, perhaps, the nearest known illustration of Hunter's idea.]

classes of animals. For instance, they are similar to the second class of the *Ovipara*[1], for the seed and the eggs are the same step.

Animals of any particular class have not one way only of propagating their species (excepting the more perfect or 1st class of animals[2]); for we have the second[3] and even the third class[4] aping the first, and attempting to be viviparous; such as vipers, lizards, and some fish[5]. We have the third class aping the second in being oviparous, with a 'white' to the egg, such as [some] fish, which in general are oviparous with the yolk only: the skate is of this class [viz. oviparous with a white to the egg[6]].

We have animals that propagate their species by slips, and that in two different ways: one by a piece cut off, the other a natural process, viz. buds growing and these falling off and producing a distinct animal; which can only take place in animals, as only that being has the power of separation and the power of afterwards catching its food, which admits of a continuation of life[7].

Many vegetables are propagated in the same manner: the Willow is a striking instance of this[8].

Vegetables being easily affected by Impressions.

Vegetables are very much affected by external impressions, much more so than animals. They have their peculiar climates in which they thrive best; and there are climates in which they cannot live, and this

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[1] [By this Hunter means the *third* class according to his 'generative' system of classification, viz. the Fishes which propagate by 'roe,' or numerous simultaneously developed eggs, of small size, and consisting almost wholly of yolk.

[2] [Mammalia.]

[3] [The 'Ovipara' with fewer and successively developed eggs, in which the yolk is surrounded by albumen and defended by a calcareous or coriaceous shell.]

[4] [Third of the 'generative system;' second of the oviparous division.]

[5] [Certain sharks, e. g. *Scoliodon*, *Spinax*: Hunter's Preparations, Nos. 3255, 3256, 3258. See also the Viper, No. 3310; Rattlesnake, No. 3316; Slow-worm (*Anguis*), No. 3326; the Viviparous Lizard (*Podarcis muralis*), Nos. 3346 and 3347.]

[6] [Hunter's Preparations, Nos. 3236–3240.]

[7] [Mr. Clift had added the following note to this passage:—"Mr. Hunter was not aware that some plants have young plants which grow from the serrated edge of a thick fleshy leaf, and, when the leaf separates from the tree, it falls to the ground, but nourishes the young plants till they strike root in the ground. Quære, the name?"—Ans. The plant is the *Bryophyllum calycinum*, Salisbury; the Preparations are now numbered 2225 A, B and C, and are described in my 'Physiological Catalogue,' vol. iv. 1838, p. 8.]

[8] [A curious exemplification of Hunter's devotion to truth, even where he immediately contradicts himself. His preparations illustrative of this property of the Willow are Nos. 2224, 2225.]

more particularly on account of the temperature of the air, every vegetable having its proper temperature, and not being able to bear much heat or cold beyond that point. They have their particular foods[1], which agrees much better with them than others: some are capable of living on dry ground, others on moist; some in clay, others in sand; some on stones, others in water.

Perhaps vegetables have not the power of retaining either their natural internal heat or cold, which is peculiar and proper for them, so much as animals have. Animal heat varies but a degree or two from the greatest external cold they can bear to the greatest heat. That many animals can retain their heat in the greatest cold is verified in the whale of Greenland. The frog is as cold in the hottest day in summer as it is in the coldest day in winter[2].

Of the distinguishing Marks between Vegetables and Animals with respect to Matter.

Vegetable and animal matter contains the same materials, but differently arranged and in different proportions. This is, in some degree, proved by chemistry; in some degree by putrefaction; but most of all by digestion.

Chemistry is capable of decomposing, but only in progression, in every stage of which a new combination takes place, which gives great variety; but no one ultimate is produced from a new combination of the whole.

There is so great a similarity between the vegetable and the animal in many of their principles of life, that we should be apt to suppose they were made up of the same composition of matter. There is nothing in their structures that could induce us to suppose this; but,

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[1] [Here Hunter expresses an important truth; heedless apparently, or unconscious, of its opposition to his previous statements respecting the all-sufficiency of water alone as the food of plants, and his reasonings thereupon as to the essential complexity of water; such supposed nutritive power of water and the consequent complexity of the fluid depending on the real nutritive particles contained in solution or fine suspension.]

[2] [This assertion neither tallies with some of Hunter's own experiments, nor with any subsequent ones. In his paper entitled "Experiments and Observations on Animals, with respect to the Power of producing Heat," Hunter writes:—"That the imperfect animals will allow of a considerable variation in their temperature of heat and cold, is proved by the following experiments. The thermometer being at 45°, the ball was introduced by the mouth into the stomach of a frog which had been exposed to the same cold. It rose to 49°. I then placed the frog in an atmosphere made warm by heated water, where I allowed it to stay twenty minutes; and upon introducing the thermometer into the stomach, it raised the quicksilver to 64°."—Phil. Trans. vol. lxv. (1775).]

in many of their operations and actions, they would appear to be so nearly allied as to make it reasonable to suppose that it was possible, even probable, for them to be composed of the same materials. But these actions are not sufficient for us to form our judgment upon [this question]; we must take every circumstance into the account before we can determine [it]. Perhaps the mode of investigating this matter is not to depend upon active principles, or the principle of life; but to consider the matter of both [vegetables and animals] when they are dying and when dead. In the first they may show a peculiarity, and in the second they can both be considered only as matter.

Chemistry was, perhaps, the first mode of investigation: but that science only considered them in two lights, viz. spontaneous changes, and those produced by fire; and, perhaps, the common modes of analysation by chemical processes have already gone as far as it was possible on this subject: nor was even chemistry employed to observe the similarity between the two substances, but to find out the products of each; which, of course, gives us the similarity and dissimilarity of the products. But, to prove the one or the other, a thousand experiments might be made which would tend to throw some light upon this subject.

I shall first consider what happens to both in the act of dying. When an animal dies it soon becomes stiff; this arises from the muscular fibres contracting in this act and not relaxing again; besides which, all the juices coagulate, which increases the rigidity. It continues in this state till putrefaction begins to dissolve the whole.

When a vegetable dies it becomes immediately flaccid, and loses that brittleness or crispness which a living vegetable has*. However, this can only happen to those whose texture will admit of it, for the woody part of a vegetable is so firm in its texture as to be little affected by death: it is like a bone in an animal. Most of the circulating juices of an animal coagulate, each by its different process: some by standing either in or out of the circulation; others by heat, alcohol, acids, &c.; excepting the red blood, which admits of being mixed with alcohol†.

The juices of plants in general do not coagulate by any process yet known‡. They readily dissolve or mix with alcohol, by which means

* Many substances kill vegetables sooner than others: vinegar is one. Therefore, those who know how to make a salad will never mix the vinegar till the salad is just going to be eaten. This effect might be supposed to be like an animal being killed by electricity or lightning; but I can only say that we have not an instance of a vegetable becoming rigid by death in any way.

† It is to be understood I speak of very fresh animal juices, for if they become putrid they will dissolve in it.

‡ Caoutchouc (India-rubber) may be supposed to be an exception to this.

we have all the 'Tinctures' [of the Pharmacopœia]. This is so remarkable that I think it might also determine the fact of itself. I find it almost impossible to keep the spirit clear [in anatomical preparations] even after a dozen shiftings; and this much more so in some [preparations] than in others.

Certain animal substances retain their native colours in spirit the same after death as before; as, *e.g.*, the shining colour of many fishes[1], the shining surface in the bottom of a cat's eye (tapetum)[2]. A cartilage, tendon, &c., are as bright in spirit as when alive; the two last are not so transparent, from the coagulation that takes place.

The native colours of vegetables do not keep in any liquor after they are dead; they all approach to the white or yellow: but this effect will take place sooner or later according as they die fast or slow. If they are made to die fast, they will retain their colour longer; if slow, they will lose it in the action of death*.

Minerals and animals give the shine to colours much more than vegetables. Polished metals are the best instances of this. Silk, some chrysalises, and beetles [have shining colours]. Vegetables give fine colours, but never polished or shining[3].

The more imperfect animals are, the more they approach towards a vegetable in many circumstances, if not all. The casting of hair is similar to the casting of leaves: much more so is the moulting of fowls, and their debility and withered combs at the time. Vegetables may be said to sleep all winter: and the winter sleeping of snakes is, as it were, living in some measure in a state of non-existence.

In their method of propagation they are similar. The egg of the animal is like the seed of the plants; and the eggs and their manner of hatching in the more imperfect animals are very similar.

Of the Dependence that Vegetables and Animals have on each other, especially the last upon the first, both in breeding and future support.

Many terrestrial animals, and probably most so those of the Insect Tribe, depend very considerably on vegetables for their support. In many of the Insects, both in their maggot and changing states, they not only feed upon the vegetable, but oblige the vegetable to grow

* Cooks and picklers are very sensible of this.

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[1] [Hunterian Preparations, No. 1884.]

[2] [Ib. Nos. 1732, 1733. See also the red pigment in parts of the skin of the Turkey, Preps. Nos. 1880, 1881.]

[3] [Mr. Clift has added the following Note:—"They are never so hard as those shining parts of minerals and animals. Some seeds are as brilliant and shining as many metals."]

suitably to their wants. Thus the female insect shall either stimulate a leaf, when it lays its eggs on it, or the eggs or the young when hatched shall stimulate the leaf to such action as shall oblige it to enclose the egg or maggot, and to prepare its future nourishment while in the maggot state. For instance, the insect while in the maggot state shall live on the leaf of a tree, using it as food; and, when it goes into its chrysalis state, it shall stimulate the leaf, which stimulus shall make it roll up and enclose the insect.

Of Motion in Vegetables.

As vegetables have not progressive motion, it must necessarily happen, that, whatever motion they have must be only a change of position of some of the smaller [and moveable] parts upon the larger and fixed; making the larger parts always the fixed. This change in the position of their smaller parts I believe arises in general from two causes, viz. stimuli or influence, and internal irritation.

To understand more thoroughly the motion in vegetables, we are to consider the vegetable itself, in most instances, as consisting of three parts: one, an old almost completely formed part; the second, a new forming part, viz. the new circle of wood and the new shoot; the third, a temporary part, as the leaf, flowers, &c., which only serve a present purpose, carrying on the operations of the plant when in its active life.

The first very probably has no motion with respect to space; the second very probably is the cause of the whole bending in consequence of external influence, as when a tree bends towards the light, or a tree on the edge of a thicket bends towards the open air and recedes from the thicket. As to the third or temporary parts; the leaves are, most probably, necessary for the growth of the new circle of wood and the new shoot; and the flowers for the seed. It is in this third [class of parts] that we are to expect the greatest quantity of motion: the already formed parts appear to be almost stationary, with respect to growth, in themselves or to that of other parts.

On the Study of Natural History.

In Natural History we are often made acquainted with the facts, yet do not know the cause. Therefore we are obliged to have recourse to experiment to ascertain the causes which connect the facts, one leading into the other, making a perfect whole; for, without the knowledge of the causes and effects conjointly, our knowledge is imperfect.

Writers on the Natural History of animals have been of two kinds—one [concerned in] only what they could observe externally, such as form and mode of life; the second [studying only] the internal parts and the structure of the whole animal, which was performed by the anatomist. As the [subject of the] first has an immediate connexion with [that of] the second, the describers of form conjectured what the structure ought to be by consulting the works of the anatomist; and the anatomist conjectured what the living history is or ought to be from the Natural History of the others; filling up what he conceived to be just, and fancy supplying the rest. But such union of knowledge does not properly match. It is one building built at different times,—an addition to an original plan. It is no wonder, therefore, that the whole is imperfect.

This [partial or restricted study] confined them very much in their mode of classing or arranging. Thus, for instance, Linnæus, catching the idea that all the animals which were formerly called 'Quadrupeds' had mammæ, therefore called them by that name [mammalia], which included the whole[1]. But, from the want of further knowledge, he has divided these again according to the situation of those parts; bringing, for example, the human kind, the elephant, the bat, &c., into one order; whereas he should only have reduced the situation of the parts themselves into different classes; [thus classifying nipples] according to situation; but not [to have] classed the animals according to those situations[2].

Of the Classes of Animals.

We divide Animals into Classes, Tribes, Genera, and Species. The three first are perhaps arbitrary; but the last is absolute [or natural]. Varieties depend neither on species nor choice, but are a kind of accident.

Classes of Animals according to their Hearts.

1. *Tetracoilia,* those that have four cavities [in the heart].
2. *Tricoilia,* those that have three cavities, which includes both land, sea, and amphibious animals[3].
3. *Dicoilia,* those that have only two cavities, as Gill-fish.
4. *Monocoilia,* those that have but one cavity, such as all kinds of Insects.

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[1] [*i. e.* not only the hairy warm-blooded quadrupeds, but the whale-kind and mankind.]

[2] [The subsequent classifications of the Mammalia by Cuvier and others show the perspicuity with which Hunter detected the artificial nature of the principal character employed by Linnæus in some of the earlier editions of the 'Systema Naturæ.']

[3] [As, for example, the Land Tortoise, the Turtle, the Frog, &c.]

5. *Acardia*, those whose stomach and heart are the same body, as in the Blubber (Medusa), Polypus, &c.

Classes of Animals according to their Breathing-Organs.

The 'first class' includes all those animals which have lungs, with cells through the whole, and a diaphragm.

The 'second,' all those which have their lungs attached to the ribs, so as to confine them to their place.

The 'third,' all those whose lungs come into the belly and are loose.

The 'fourth,' all those whose lungs are in their necks, called gills.

The 'fifth' are reptiles, whose lungs are in their sides[1].

Classes of Animals according to Essential and Circumstantial Characters.

The characters of the 'first class,' which includes land and sea animals, are:—A heart made up of four cavities: essential. The lungs confined to a proper cavity, the enlargement of which is the cause of respiration: essential. Lungs divided into small cells: essential. Respiration quick: essential. Viviparous, and I believe the only animals that are [truly] so: essential. Give suck: essential. Parts of generation: in the male, made up of testes and one penis, the testes sometimes within and sometimes without the abdomen, but pass forwards: in the female, a clitoris, vagina, uterus, os uteri, fallopian tubes, and ovaria: all essential. Kidneys high up in the abdomen: circumstantial. An external canal to the ear: circumstantial. Membrana tympani concave externally: circumstantial. A cochlea: circumstantial. By much the most perfect animals, whether sea or land.

There is a gradation from the land to the sea-animals, viz. Otter, Seal, Hippopotamus, Whale.

The 'second class' is composed of the Bird entirely. I do not know of any animal of this class but has all the characteristics of the bird. They vary less in any of their parts than the first class.

Lungs: attached to the ribs, that they may move with them; lungs perforated: membranous bags in the abdomen that receive the air in respiration: something similar to a diaphragm.

Parts of Generation: ova crustaceous; one oviduct; one penis, and that grooved; no bladder; [outlet of the] oviduct [in the female] and penis with the [openings of the] vasa deferentia [in the male] all in the same cavity with the anus.

[1] [By 'reptiles' Hunter signifies 'creeping things,' or Invertebrata in general; and consequently his fifth class would include most of those which possess respiratory organs, as Insects, Crustaceans, Mollusks, and most Anellids.]

Liver: divided into two lobes; cyst-hepatic ducts[1].

Organ of Hearing: little external passage to the ear; membrana tympani convex externally, and with but one bone [ossiculum auditus]; no cochlea[2].

Feathers; wings; two legs; long neck; a bill; a membrana nictitans; bursa [Fabricii].

None of this class are entirely sea-animals; but it may be said to possess in some measure three elements, viz. air, earth, and water: but they live no more in the air than other animals; it is only for their progressive motion[3].

In the 'third class' we shall find some parts similar [to those in the second]. The third class may be divided into two; for they are not exactly alike, but one seems to partake of the second and third, as it were, made up of both. The first division of the third class, then, is the Lizard and Serpent kind. They have:—

Heart: two auricles, one ventricle, two aortas which unite in the abdomen.

Lungs: loose bags, which lie in the thorax and abdomen, only partially divided[4]. No diaphragm.

Kidneys: in the lower part of abdomen. No bladder[5].

Parts of Generation: two penises, which are in the tail, and are grooved. Some are oviparous, eggs without [hard] shells; others are viviparous, but not as in the first class.

Some have legs, others none; some a membrana tympani which is convex outwardly, as in the lizard[6]; others none, as in the snake[7].

The other part of this class, which may be called the 'fourth,' or the Amphibious, is more fishified than what the fish of the first class [Cetacea] are. The common amphibious animals are frogs, turtles, crocodiles, &c. This [class] is very similar to the two former, and is nearly, as it were, a mixture of both; yet the most essential parts belong, or are similar to the last:—

Heart: two auricles, one ventricle[8], as in the Third.

Lungs: as in the Third; aorta as in the Third; no diaphragm.

Kidneys: as in the Third.

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[1] [Hunt. Prep. No. 816.] [2] [Hunt. Prep. No. 1581.]

[3] [Air is not more essential to the life of birds than of other animals; their especial relations are to air as a medium of locomotion.]

[4] [Hunt. Prep. Nos. 1105–1109.]

[5] [This character applies only to serpents, not to all lizards.]

[6] [Hunt. Prep. No. 1576.] [7] [It exists, but adheres to the skin.]

[8] [Hunt. Prep. Nos. 915–919 (*Amphiuma*), (*Chelone mydas*): the preparation of the heart of the crocodile, No. 921, is so dissected as not to show the complete septum of the ventricular cavity, peculiar to the *Crocodilia*, among reptiles.]

Parts of Generation: one penis, as in the Second; penis grooved[1], as in the Second and Third. Some are oviparous, as frogs, &c.[2]; others viviparous, as the salamander[3].

Organ of Hearing: some have a membrana tympani, as the frog; others none, as the tortoise[4].

The *Fourth* or *Fifth Class* is very distinct from the former, as far as I know.

Of the Similarity of many Parts of the Fowl and Three-cavity-hearted Animals, especially those called Amphibious.

The lungs of the fowl open into thin cells or bags that are in the cavity of the belly. The cells of the lungs are large. The lungs in the *Tricoilia* are continued into the belly, are cellular at the upper part, but in most, *e. g.* the snake, become smooth bags at the lower end[5]; as it were, answering the same purpose as the abdominal bag in fowls: the cells of the lung-part are large. No proper diaphragm in either class: but fowls have something similar to one. The gall is green in both. The kidneys are placed in what may be called the pelvis, in both[6]: they are conglomerated in a particular manner, have the ureter ramifying through their whole substance[7], and it enters into the rectum. The urine is a chalky substance in many of both classes, and is a kind of slime in others. The testes are situated in the abdomen, in the males of both. The vasa deferentia enter the rectum in both. The penis is grooved in both. Both are oviparous. The structure of the ear is similar. The heat [of the body is] very different [in the two classes].

Classes of Animals according to their Brains.

Of the First Class of Animals that have Organs of Sense, and consequently have Brains[8].—The brain in this class of animals is scarcely

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1 [Hunt. Prep. Nos. 2444–2452.] 2 [Ib. Nos. 3270, 3271.]

3 [Ib. Nos. 3296–3299.]

4 [The homologue of the ear-drum exists in all *Chelonia*; but, as in *Ophidia*, the membrane is less distinct and free from adhesion than in lizards and frogs. Hunter's division of the *Reptilia* of Cuvier into two classes is founded on the generative organs. The *Crocodilia* and *Chelonia* are separated from the *Lacertilia* and *Ophidia* by having the intromittent organ single, instead of double. Hunter's error lies in associating them with the Cuvierian *Batrachia*, which have no intromittent organ; and have modifications of the procreative system which led Hunter himself to make the separation, and place the Batrachia with Fishes in the 'generative' system of classification.]

5 [Hunt. Prep. No. 1088.] 6 [Ib. Prep. Nos. 1179–1183.]

7 [Ib. Preps. Nos. 1189–1195.]

8 [The preparations (Nos. 1304, 1305, 1306) which illustrate the condition of the nervous system characteristic of this 'class' are derived exclusively from the Mol-

similar in any respect to that of the most perfect animals with which we are in general more acquainted. It consists of a pulpy substance, somewhat transparent, which is easily squeezed out when the brain is cut into. It appears in some, and perhaps in all the lower classes that have brains, in the shape of a ring, from the circumference of which arise the nerves, as radii from a centre. Through this ring (in such) passes the œsophagus. I am apt to believe, however, that this ring is not wholly brain, but a union of two large lateral nerves, which unite under the œsophagus. This at least appears to be the case with the next class. It is not enclosed in hard parts, and is not defended from pressure or injuries more than any other internal part.

This class would appear to have but two senses, viz. feeling and taste, having neither seeing nor hearing, and most probably without the sense of smell. There appears to be no organ for such a sensation, and the respiratory organ is so situated as not to be of any service to taste, to which smelling is certainly a director.

Of the Second Class, or Insects.—The class of animals immediately superior in sensation to the foregoing is (I believe) that class called 'Insects,' both aërial and aquatic. We find in them an increase of senses. The first class we were inclinable to believe had but two senses; but here we are pretty certain of four, viz. touch, taste, hearing*, and sight: how far they have smell I have not been able to discover, but should doubt it†.

The brain lies in the head of the animal, and consists of a small rounded body, giving off nerves in all directions to the different parts about the head, such as the optic nerve, &c. The brain is a pulpy substance, somewhat transparent, which gives it a bluish cast. From the posterior or lower part of the brain, close to one another, go out two large nerves; one passes on each side of the œsophagus, and they then unite into one, forming a knot at this union‡. They disunite again, and so unite and disunite alternately through the whole length of the animal, at every union giving off the nerves, as from the brain. This structure I suspect answers both the use of a medulla spinalis and the great intercostal nerve[1].

* It is pretty certain that bees hear.

† Yet it would appear from observation that it is very probable that bees and wasps have smell.

‡ It is the union of these two nerves, and the œsophagus passing through between them, which made me suppose that that in the Snail was a similar structure.

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luscous subkingdom of Cuvier, whence it may be inferred that Hunter had a perception of that great natural subdivision of the animal kingdom].

[1] [The complicated abdominal cord of Insects has since been accurately figured and described by Lyonet and other anatomists, and has recently been successfully

Of the Third Class, or Fish.—This class of animals is a considerable remove from the former in complication of structure. We have observed that they have a complete circulation, making in the whole almost a second.

They are endowed with five senses.

The brain in this class is, upon the whole, much larger in proportion to the size of the animal than in the former. It is a very irregular mass; but the several parts that are similar to those in a still superior order may be picked out. The brain varies in shape in this very much more than in any other class of animals. The cerebrum in some, as in the Skate, is detached to some distance from the other parts; in others it is pretty closely connected. There are more parts in some than there are in others.

They have a medulla spinalis, or continuation of the brain down the back.

In the first class we had the brain surrounded by soft parts only. In the second it was closely surrounded by soft parts, but these were surrounded by hard. In the present class the brain has a case of hard parts for itself, called the skull; but it is too large for the brain, therefore this is attached to the skull by a cellular membrane, which makes a kind of tunica arachnoides[1].

The nerves arising from the brain in this class are very large, and there seem to be nine pairs.

Of the Fourth Class, or Amphibia.—The brain in this class is very small in proportion to the size of the animal, smaller than even what it is in the former, or Fishes.

It would seem from external appearance to be made up of many

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studied in relation to the modern discoveries of the functions of the several parts of the spinal chord of the vertebrate animals. Mr. Newport (Phil. Trans. 1834, p. 405) describes the abdominal cords of insects as composed of two tracts, a ganglionic or sensitive which is anterior or ventral, and a motor tract which passes over the ganglions on the posterior or dorsal aspect. In addition to these there is a narrower column on the posterior part of the motor tract, which he calls the involuntary tract, and would therefore more immediately answer to the sympathetic or great intercostal nerve. These parts in the Crustaceans and in the imago of the Insect are protected by a specially investing substance, of which Hunter appears to have been aware from his assigning the floating or unprotected condition of the nervous centres as a character of his first class.]

[1] [The mode of progression of fishes requires that the head should be of large size, to divide the water and to afford adequate attachment to the mass of muscles passing to it from the body. The mode in which this is effected without incurring an undue accumulation of ponderous matter about the brain, is now acknowledged to be that which Hunter has described, viz. by an extraordinary development of the arachnoid covering, the cells of which are filled with a serous fluid; and upon this is the skull moulded.]

parts, which are not hidden, or do not lie one upon another, but are very much detached and follow one another, or are more in one line or direction, and not compacted. The whole is an oblong body composed of five eminences, with their common basis.

The two anterior consist of the cerebrum; the two middle I should suppose of the nates and testes, which I suppose to be the middle lobes detached; because, in the Bird, they are more underneath, not so much between the cerebrum and cerebellum. The posterior is the cerebellum, consisting of one body entirely.

It would appear as if the order of size was inverted, viz. the two middle bodies seem to be the nates and testes, yet they are much too large to bear the same proportion as in the higher classes. Every eminence has a cavity or ventricle in it, therefore, in this class, there are five cavities or ventricles. The cavities in the cerebrum are larger than in the others, and are similar to those of the higher classes, *i. e.* they have a large eminence projecting into the cavity, which is the major part of the brain in the Bird. In the others the cavities seem to be pretty near of the shape of the body or protuberance in which they are; and they are very large in proportion to the size of the brain. The tunica arachnoides covers almost the whole brain. It does not adapt itself to the eminences and cavities, but is connected with the pia mater by a cellular membrane on its inside, and to the skull, or dura mater, on its outside.

There are no convolutions on the external surface of the brain, but it is covered smoothly by the pia mater.

The nerves arising from these brains are very large, nearly as large as in the human.

There are ten pairs that go out of the skull, and the accessorius joins the ninth pair.

The first pair are very large at their beginnings, becoming very small at once, which has the appearance as if they arose from two small round bodies.

Although the Crocodile is classed with the *Amphibia*, and really comes nearer to that class than to any other that I know of, it has not all the same character, as has been observed. It comes nearer the Bird than any of the other *Amphibia* [do], and therefore is a degree higher[1].

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[1] [The justness of this observation is confirmed by the systems proposed by many modern naturalists for the classification of the *Amphibia* of Linnæus. Merrem separates the Crocodiles from the other Sauria of Cuvier, to form a distinct order, which he terms 'Loricata.' Latreille also separates the Crocodiles from the Lacertæ, but joins them with the Chelonians to form his section *Cataphracta*. My experienced colleague Dr. Gray joins the extinct *Enaliosaurii* with the Crocodiles to form his order 'Loricata.']

The brain, although it has the same parts, yet it has them closer connected, and the skull is more in contact with it.

Of the Fifth Class, or Fowl.—The brain in this class is larger in proportion to the size of the animal than in the foregoing. It consists of the pulpy substance, but is not very distinctly of two kinds, cortical and medullary.

It would seem to be made up of six parts, viz. the two hemispheres of the cerebrum; the two round bodies, one on each side of the medulla oblongata, pretty much detached, which would seem to answer to the two middle lobes, although their situation with respect to the skull is different, for they are under the lateral processes; fifth, the cerebellum; and sixth, the medulla oblongata, which is the common base. The cerebellum is considerably behind the posterior lobes, and is large in proportion to the size of the whole brain.

The two hemispheres do not seem to unite, although they are so close to one another as to be hardly separated by means of the inner sides of the two lateral ventricles. The two lateral ventricles are very large, and may be called the broad cavities; they begin forwards near the anterior points where the olfactory nerves arise, and near that surface where the two hemispheres are in contact with one another; each ventricle passes backwards, and winds round the posterior end, but does not extend so far to the outer or lateral parts of the hemisphere as to come forwards again. The part of the brain which makes the inner and posterior wall of this cavity is very broad, and so thin in many places as to appear like a membrane or pia mater only. On the inner surface it is concave, on the external it is convex, and the opposite or inner side of the cavity, which is the major part of the brain, is convex, which answers to the concavity of the outer; so that the two surfaces are moulded to, and in contact with, one another. When this outer portion is taken off, the brain is nearly of the same shape and size as before. The plexus choroides is a vessel which comes from the lower part of the cavity of the two thalami, or from the upper surface of the medulla oblongata, and runs backwards and upwards through the cavity, and spreads into a broad loose flat fringy end. At the lower part of the division of the two hemispheres is the third ventricle, like a groove; the anterior end terminates in the infundibulum below the optic nerves, but at some distance; the posterior end is continued into the fourth ventricle in the quadruped, or the sixth ventricle in this class.

The two lateral bodies[1] which are on the sides of the medulla ob-

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[1] [The optic lobes, or bigeminal bodies.]

longata, and somewhat under the posterior lobes of the cerebrum, somewhat in the situation of the cerebellum in the next class, are equal in size to one-sixth of the whole brain. They have each a cavity in the middle, which make the fourth and fifth ventricles, and these communicate with, or enter at, the communication of the third with the sixth, so that all those six ventricles communicate with each other.

The cerebellum is a prominent pyramidal body, standing on the posterior and upper part of the medulla oblongata, behind and somewhat between the posterior lobes of the cerebrum and in contact with them: it is more convoluted than the cerebrum, which convolutions are sometimes similar to the human.

Of the Sixth Class, or Quadrupeds.—The brain in this class is, in general, larger than in the preceding, and the parts more compacted, the whole mass being brought into nearly a globular figure.

The cerebellum is more immediately under the cerebrum, and the convolutions in the cerebrum are deeper[1].

The nates and testes are four small bodies, with no visible cavities, which are not seen externally, but lie at the posterior end of the third ventricle.

The ventricles are only four in number[2]. The two lateral ones communicate under the lower edge of the septum lucidum, and are pretty large; beginning in the anterior lobe of the cerebrum by a blunt end pretty far forward, going directly back, and when got some considerable way, bending outward and downward, then forward and still down- and also inward, and ending nearly under their origins. In them lie the corpora striata, the thalami nervorum opticorum, the plexus choroides, and the fornix. The third ventricle is directly under the fornix, and communicates forwards by a small opening with the infundibulum, which goes down to the pituitary gland; behind, it communicates with the fourth ventricle, which is partly in the medulla oblongata.

The cerebrum and cerebellum end by four peduncles in the tuberculum annulare, and the medulla oblongata goes out from it; at the going out of which are four pyramidal bodies, viz. the corpora olivaria, and corpora pyramidalia.

In the brain the cortical substance is on the outside, in the medulla spinalis within; in some it is in one line running down, in others two.

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[1] [This applies only to the orders *Cetacea*, *Ungulata*, *Carnivora*, and *Quadrumana*, associated together as 'Gyrencephala' in my "Cerebral System of the Mammalia," Proceedings of the Linnean Society, 1857.]

[2] [The interspace between the layers of the septum lucidum is now regarded as constituting a fifth ventricle, and is peculiar to the Mammalia.]

The nerves which go out of the skull are nine pairs, and the accessorius, which goes out with the eighth.

Classes of Animals according to their modes of Generation.

1. *Vivipara*; those that bring forth [living young, formed] in the uterus, from a mixture of male and female influence: such are all of the first class [according to the structure of heart and lungs], both sea and land.

2. *Vivum ex ovo* [*ovovivipara*]; those that may be said to hatch their young from an egg in the oviduct; as, *e. g.*, most vipers, slow-worms, some lizards, salamanders: and this is confined to part of the second class of hearts [*Tricoilia*] and to some of the third [*Dicoilia*], as in the [piked] dog-fish.

3. *Ovipara*; those that throw their eggs out and are hatched out of the body. This takes in a large field, viz. part of the first class [*Tetracoilia*, i. e. Birds] and of the second class [*Tricoilia*], the greatest part of the third [*Dicoilia*], and perhaps all of the fourth [*i. e.* those with lungs in their sides].

4. The mode of producing a continuation of the species in animals may first be divided into two kinds: the one [by products of organs of generation, as above defined]; the other, which is the most simple, is a part of any one animal becoming a whole, and, what is somewhat similar, producing an animal out of itself—like a branch of a tree or a sucker from a root: these [fissiparous and gemmiparous modes] admit of considerable variety.

There are three classes of animals which may be called oviparous[1]; the Bird, the Amphibia, and the tribe of Ray-fish.

The Bird and the Amphibia are nearer each other in their operations: but in some circumstances the Ray-fish is the same as the Amphibia, in others very different. They are different, *e.g.*, in the construction of their eggs: they are somewhat different in their mode of receiving the yolk into the abdomen.

Classes of Animals according to the Coitus.

In the first class they are male and female, and they insert[2]. In the second they are male and female, but do not all insert; some only

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[1] [Here the word is restricted in its application to the animals which exclude comparatively few and large eggs, and those successively, in contrast with the numerous and simultaneously discharged small eggs of frogs and roe-fish.]

[2] [This applies to the *Mammalia*.]

aping the first[1]. In the third[2] they are male and female, but do not insert. The fourth[3] are some male and female distinctly; others are Hermaphrodites, but [of these some] propagate with each other, while some copulate with themselves; thus some ape the more perfect, others not.

Division of Animals according to their Temperature.

Animals should not be divided into the 'Warm' and 'Cold.' They should be divided into those of permanent heat, in whatever climate, and those that change [in heat] with the climate. For the snail, which lives in the hot baths in Italy[4], lives in a warmer atmosphere than the heat of the animals of permanent temperature; therefore it must be warmer than the permanent.

These divisions [of 'warm-blooded' and 'cold-blooded' animals] were made by Naturalists of cold climates.

In proportion to the coldness of animals they cannot bear cold weather; viz. snails, snakes, lizards, &c., cannot bear the cold. A whale can live in Greenland all winter, but the cold fish come south in winter.

Classes of Animals according to Size of Body.

The Quadruped [Mammalia] is the largest class of animals [*i. e.* includes animals of the largest size, *e. g.* whales, elephants, rhinoceroses]. The Amphibia probably next [*e. g.* crocodiles]. Fishes are the third [sharks]. Fowl the fourth (ostriches, &c.). Insects of the first class [Crustaceans, *e. g.* crayfish, lobsters], the fifth. Insects of the second class, the sixth.

Division of Animals according to the Element they frequent.

All animals must have certain general principles, or they would not be 'animals;' and it is the different combination of these principles that produce different animals: the classing of animals is no more than the classing of those different combinations, for there is a great regularity in the variations.

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[1] [This character would apply to *Aves*, the exceptions being the *Struthionidæ*, *Anseres*. If by the 'second' Hunter means his 'second class according to hearts,' or 'Tricoilia,' then intromission is the rule, and the Batrachia the exception.]

[2] [Here the 'Dicoilia,' or third class according to hearts, i. e. *Pisces*, is evidently meant.]

[3] [The 'Monocoilia' may be here meant by the fourth class; but the generative character would apply to the *Invertebrata* at large.]

[4] [The *Cyclostomum thermale* of the hot-springs of Abano moves about with great activity, and propagates in water of the temperature of 100° Fahrenheit.]

The first principles are but few; but it is the various forms of those principles that produce such variety of animals. Out of these principles Nature has first produced three classes of animals to answer the three elements; therefore there is a similarity in each class, more than between any two of these classes. This is the first division: these are subdivided into a great many fitted for other variations of nature. As a general description would answer all animals, viz. what an animal was, and as the animals are divided into three classes, so must the description; then each class is again subdivided, which subdivides our description[1].

In treating of any one animal, tracing it through the circle of life, we move as it were in a circle: for, at whatever stage of its progress we begin, we come to the same stage again before we complete the whole circle. If we begin at its rise and go through its whole progress, we are led naturally to the same point again, viz. to the production of another animal similar to the present[2].

Of perfect and imperfect Animals.

Nature has, in the most perfect animals, formed parts very distinct from one another, for all the different functions or operations of the body; whereas, in the more imperfect, she has huddled parts together, and made some serve two purposes, or has joined two into one. For instance the ureters of the Bird enter the anus;—the penis, vasa deferentia or oviducts, enter the anus[3]. Still more imperfect animals have heart and stomach in one.

The more imperfect animals are, the greater is the tendency or disposition they have for parts which have been removed to be restored.

I gelded a young cock; and, after having let him live eight months, I found that a small part which had been left was become much larger. [By the way, talking of cocks] cocks' combs are parts that do not inflame though ever so much wounded; this we see in cutting them when they have fought, &c.

Progression and Declension of perfection in Animals.

What we call 'perfection' in animals does not increase in regular progression in every part, but as animals are complicated; and each

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1 [This characteristically Hunterian MS. may healthily exercise the ingenuity of some readers to decipher its full meaning.]

2 ["The organs of animals form the links of a chain, and their functions form a continued circle of renovation and decay."—Cuvier.]

3 [Here Hunter enunciates the principle of 'differentiation of structure' as characteristic of grade. He might have cited many better examples, and such will readily suggest themselves to the naturalist.]

complication has its degrees of perfection. These degrees do not correspond in perfection; [they are not] regularly progressive in every part from the most imperfect to the most perfect [animals]: although they go on in pretty regular steps of perfection among themselves. Thus, Fish are an inferior order of beings to Fowl; yet Fish have teeth, a property belonging to the highest order; therefore Fish in this part step over Fowl. The Amphibia, which are between Fish and Fowl, in this respect resemble both, having both teeth and bill[1]; but then they are most like the Fowl in the vital parts, whilst they have teeth like the Fish.

Perhaps the declension of animals from the most perfect to the most imperfect is in a regular order or progression; but that progression is far from being an equal one; for the differences or distances between, or amongst, the most perfect are great and obvious; but when we come among the imperfect they are much closer, or less observable, if at all.

This makes the most perfect but few in number in comparison with the others; and, in these, increases the number of genera and species; and removes the Human to the greatest distance, which is an agreeable reflection.

The declension of animals from the Human to the brute, or more distant brute, is faster in the head and trunk than in the four extremities. The trunk of a mangoose, &c. (*Lemuridæ*), is nearer that of a cat or dog, than its four extremities. The trunk of a bear is quite that of the brute, but the extremities are nearer the human hand and foot.

The more perfect animals, as Man, dogs, &c., grow in size in all seasons of the year; however, it is probable that the cold season may have some effect in hindering the growth of the animal very sensibly. The more imperfect animals have their particular seasons of growth, similar to vegetables. This I should suppose is peculiar to all those animals which sleep through the winter.

On the Origin of Species.

Does not the natural gradation of animals, from one to another, lead to the original species? And does not that mode of investigation gradually lead to the knowledge of that species? Are we not led on to the wolf by the gradual affinity of the different varieties in the dog? Could we not trace out the gradation in the cat, horse, cow, sheep, fowl, &c., in a like manner[2]?

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[1] [The lizard, Prep. No. 386, has teeth; the tortoise, No. 2105, a bill; the siren, No. 1063, has both.]

[2] [The best attempt to answer this supreme question in zoology has been made by Charles Darwin in his work entitled "On the Origin of Species by means of Natural Selection," &c. 8vo, 1859.]

It may be difficult to find out the original of any animal that is not probably now found wild. It will be difficult to say which is the original cow, whether the East India cow or the European; but, as the East Indian has the least variety of the two kinds, it is therefore more probably the original cow than the European. Besides, this animal came from the East, and was more likely to go through varieties in new countries [*i. e.* under new external influences] than in its original country.

Varieties of Animals.

Any variety in animals that is pretty constant is commonly called a 'breed:' such as of hogs, cattle, sheep, horses; although such, in some species, as in dogs, go by particular names, as bull-dog, mastiff, greyhound, &c.; and, therefore, in such the word 'breed' would be applied to each; as a breed of bull-dogs, &c. In hogs, cattle, &c., a breed often goes by a particular name, as the Chinese breed of hogs, the Welsh breed of sheep, the Holderness breed of cows, the breed of running-horses, &c.

These different breeds of the same species, although they be pretty constant in their hereditary properties, and by getting the breed we are pretty sure of the produce, yet they are often varying from the true breed; and these are either better or worse than the original: but, whichever it may be, it in some degree becomes an hereditary principle.

The varieties among the original of any species of animals are much less than the varieties of any of the varieties. Thus wolves have less varieties among themselves than we find in any of the varieties of dogs; whether we take the bull-dog, mastiff, greyhound, &c. The same may be observed of Man.

Varieties are so regular as to be classible: thus we have dogs of particular kinds, cows, cats, fowls, horses, sheep, &c.

How far varieties in animals are gradual, or in what degree they, at once, produce a very distinct variety, is perhaps not to be ascertained. But, if it be gradual, we should then be able to trace most varieties up to their original. Did the peacock, the turkey, the guinea-fowl, &c. become first spotted or pied, and the pied then produce the white? Or was the white produced at once by an original?

I believe that all varieties that seem to be an amendment in themselves, such as increase of size, are as little profitable respecting breeding as what the originals are. For, where the profits depend on the readiness to have young and their number, I believe they are less profitable. Thus the common pigeon breeds better than the varieties, especially the runt: the common fowl better than the larger, or shaklebag.

It would appear that a variety was more permanent in its principles than an original. I do not mean a variety arising out of an original; for the wolf that was lined by a dog, had the puppies more like the dog, at least in colour, than the wolf. The same with the jackall, both in the first change and the second litter.

However, this was not the case with the offspring of the white Negro: therefore we must suppose that such are only half monsters respecting breeding, similar exactly to a mixture of two original varieties. Original varieties are, therefore, either perfect or imperfect: and next come the varieties of mixture, or of one original with another.

Animals in proportion to their powers of sagacity are more easily moved from their instinctive principles than those that are less so; and such therefore are more easily domesticated; and, probably, from this circumstance, they may more readily admit of greater variety in their offspring. The dog appears to explain this, as strongly as any other species. The dog is a sagacious animal; the varieties he has gone into are almost endless, as also the dispositions of each, for they seem to have gone as far from the original, or the wolf, in disposition—in what may be called their instinctive principles—as they have in size, shape, colour, &c.

Mr. Walsh[1] informed me he put a wolf-puppy among some dog-puppies. The wolf was asleep all day and awake all night; the dogs the contrary.

On the Natural History of Man.

Superiority of Man according to Mind.

All animals bear a pretty close comparison with one another[2], excepting the Human; because they are all ruled by natural and instinctive principles. But the Human, being an animal of art, when he is compared with others, it should be in regard to his instinctive principle only. Animals may be compared to one another in their facility to learn, the Human being at the head; and probably brute animals are capable only of learning, the Human being the only animal capable of invention.

Is not the Human Being a congeries of every animal? Has he not the instinctive principles of every animal, with this difference, that he chooses or varies the mode of putting those principles into action?

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[1] [John Walsh, Esq., F.R.S., the friend of Benjamin Franklin, and to whom Hunter was indebted for the specimens of Torpedo which he dissected and described in the Phil. Trans. vol. lxiii. 1773.]

[2] [Animals, in regard to psychical qualities, bear a pretty close resemblance to one another (?), excepting, &c.]

He adapts the instinctive principle to the situation or to the whim. He must eat; but he varies the mode of eating: he takes the advantage of circumstances and applies them ; he takes the advantage of all nature. Each bird builds its nest in a way peculiar to the species; Man builds his, but he does it in a way most suitable to the situation or pleasure.

Nothing shows more the superiority of the Human over the brute, than the variety of ways in which he shall perform any natural and instinctive action.

Superiority of Man according to Frame.

Every circumstance in life, and most things in the structure of the body, show that it was intended by Nature that the Human body should be, in general, erect, especially in its progressive motion. The position of the face; the shape of the chest, being wider from side to side than in animals which are horizontal; the spine projecting forwards in the thorax so as to throw part of the chest behind, and the different curves of the column, with the head at the upper part, to break the force of concussion in walking, jumping, &c.; the pyramidal figure of the whole spine; no 'ligamentum nuchæ' to supersede muscular contraction ; the strong attachment of the os sacrum to the ossa ilii; the great disproportion of the length of the legs and arms (excepting he had been a jumping animal); the length of foot is also a strong proof of the erect position.

Nothing can be more absurd, more unphilosophical and more ungraceful, than the satyrs of the ancients.

The erect position of Man is probably the worst calculated for either natural offence or defence of any animal posture. His body becomes wholly exposed: it is even unfit for resisting the force of either wind or water. But, at the same time, we must allow that it is the best calculated for artificial defence; it is more capable of bringing in aids to this end: the arms are at liberty: the whole body can move on the feet as on a centre to increase the action of offence or defence.

Of the Use of the Feet in Man.

The use of the length of foot in the Human is to increase the basis from the fore to the back parts: the two feet increase it laterally. They add to the length of the step, and they are to the legs what fellies are to a wheel, which are to make the whole go more equally round ; they serve therefore to make our steps more equal. This is evident by comparing the walk of a man with wooden legs with that of one having a natural pair of healthy and sound legs. The former goes like a wheel upon the spokes, but the latter equally and easy. A man with a wooden leg is obliged, likewise, to turn his side forwards, belonging to the leg that is moved, so as to humour the step.

Of the Bow-leg.

What is commonly understood by a bow-leg is where the knees are at a greater distance [than usual] from each other; in which case the femur and tibia are more on a line with each other. Therefore, upon a more critical knowledge of this part, what is commonly called a bow-leg is, in reality, a straighter one than where they have the general appearance of being straight.

This is the natural or original construction, for all children have what is commonly understood as 'bow-legs;' and, if strong, they continue so; and, any deviation from that, is a mark of weakness; for the support, or perpendicular columns, are the bones; and, the straighter these are, the stronger they will be, or the abler to support the weight.

Bow-legged people generally have their toes turned directly forward. This I should suppose arises from the original cause, viz. that of strength; for all children are born in-toed, corresponding with the bow-legs; and what supports this [view] is, that all those who are in-kneed turn out their toes very much. Thus it is demonstrable, from the foot being at a right angle with the leg, why strong children should turn their toes directly forward, and weak children turn theirs outward.

Children are not only weak in their bones, but also in their muscles. The child is not in the least conscious of a weakness in the bones; they obey the intention of the muscles: while at the same time it has a desire for these motions, and therefore tries: and, in these trials, finds out the easiest method for motion: for these trials naturally throw the parts into such positions from the weight of body, or from the resistance, as are easiest for the child to move in, but very far from being the best.

The foot is to be regarded as of considerable length, compared with breadth; and, as has been observed, the most projecting part of the foot is turned forward beyond the column of the body, in the line of progressive motion. In walking, then, it requires considerable muscular strength to raise the body, and throw it forwards, as it were, upon or over the toes: for, if there was no projecting part of the foot, no muscular strength would be required, and one, then, would walk as people do on wooden legs.

In proportion as the toes are turned forward it requires a greater strength of muscular action to throw the body upon the toes; for the force or resistance of the body acts with the longest lever, and this lever becomes less in proportion as the toes are turned out. Now, as this is the case, we see a reason why young children, who are weak, turn their toes out: they find that they can walk in this manner when they cannot in the other way; and, in proportion to their weakness, will they turn out their toes*.

We find, too, another circumstance that allows them to move; which is, the joint of the ankle being allowed to flex more than it otherwise would be allowed to do if the raising power was sufficiently strong to keep the foot extended. They find that they can throw their bodies forward without being obliged to raise the heels; which they are not able to do, and which bends the leg forwards upon the foot. And in this way are children allowed to move, which is allowing them to act before they have strength to use their joints properly and give them those determined motions that the mechanism of the parts require. Therefore, the joints are obliged to submit to the inconveniences arising from too great a weight of body. Mothers and nurses are so fond of seeing their children walk, that they are always endeavouring to teach them what they are unable to perform; and, finding that a child cannot really stand without a strength proportionate to the weight of body, they have contrived 'leading strings' to support the superabundant weight, so that the child may be enabled to use its legs (that is, to set one leg before the other). By the time it arrives at its strength of standing perpendicularly, it has not, however, arrived at a strength sufficient to support the body in motion, where it must be often thrown out of the perpendicular, when one leg, for example, must be able to raise the whole body upon its toes, while the other leg is in motion.

But the child has unluckily, by this time, acquired a knowledge of progressive motion and a desire for it; yet has not acquired strength equal to perform it properly: and, therefore, the muscles and joints must submit to give way to the weight of body and to fall into those positions that require the least strength of body to move in.

Dancing-masters apply this position of foot, which arises from weakness in children, to their profession: for, in many of their violent motions, a greater strength is required than what the parts are capable

* It is not to be supposed that the child turns its toes out by design; but it is in consequence of weakness. When the child endeavours to raise itself upon the toes, the muscles are not able to do it, but the heel is brought forward, which turns the toes out; and at last the child gets a habit of it, and the foot naturally takes this turn.

of exerting: but this position of foot allows of much quicker motions than what otherwise could take place, and likewise allows of those easy graceful lateral motions, that they practice, from the base being enlarged laterally; and it does not in the least hinder the perpendicular spring.

These observations I was led to, from an accident which produced that weakness in me that attends children,—which was a rupture of the 'tendo Achillis;' for, before the tendon had sufficient strength to raise my heels, so as to raise myself upon my toes, I was obliged to turn my toes out, to avoid the pain that I had when I acted with my 'gastrocnemius' and 'soleus' muscles, and in this way I could walk tolerably well.

The Difference between Man and the Monkey.

The monkey in general may be said to be half beast and half man; it may be said to be the middle stage. However, there is one thing that makes the monkey come nearer the brute, viz. the toes being similar to fingers. Our toes bear but little resemblance either in size or use to our fingers; our feet are made for walking upon, but our hands are made for laying hold. The toed brute has its hands and feet made to answer nearly the same purpose; it walks upon them almost equally, and lays hold of things with both; and [the limbs] are therefore very like one another. The monkey [is, in this respect], quite the same; for they use either hand or foot, or either feet, with the same ease. In this circumstance also the monkey is like the brute; viz. the fore- and hind-toes are like one another; but they differ very much from the toes of brutes.

The monkey cannot bring its body and lower extremities into so straight a line as the human [kind can]; the foot is not arched, but is a little bent in the contrary direction; it is longer in proportion, but is not so broad nor so thick, as in Man. The thighs are flattened between the inside and outside; but are broader in the other direction; the joint of the knee is not so straight; the legs are flattened like the thighs. The joint of the elbow does not extend so far; the rotation of the radius is not so great. The four extremities are more of a length. The two first bones of the extremities, viz. the humerus and femur, are shorter in proportion to the radius and ulna, or the tibia and fibula. The toes or fingers are narrower laterally, but thicker between the back and fore-parts, which make their nails so much the narrower. The thumb of the hand or fore-foot is not so strong, and has not that opposing motion [in the degree which man's has]; some [monkeys] want this altogether [fore-thumb][1]. The thumb of the foot is not at all like that

[1] [See Ogilby, "On the Opposable Power of the Thumb in certain Mammals," &c., Proceedings of the Zoological Society, vol. iv. p. 25.]

of the Human. The sternum is not so near the back-bone. The trunk of the monkey is not so flat from fore to back, so that the ribs are not so crooked; especially the first rib, which makes it flatter between the right and left sides; and this obliges the vessels arising from the great curvature of the aorta to be fewer and closer to one another. The iliac bones do not spread forward and fly out laterally, but rise higher or are longer. The sacrum is not so pyramidal. The symphysis pubis is longer. The tuberosity of the ischium projects further back or down. The whole pelvis is not so much thrown back. The spine does not project so much in the thorax. The clavicles are not so long; so that the shoulders do not project so far out and back; therefore, of course, they are more forward and are nearer the sternum.

The head is not so broad laterally, but is longer between the upper part of the occiput and the mouth, and is not so deep between the os frontis and basis cranii. The face is oblique, and is not transverse as in many brutes, nor in the direction of the body, as it is in the human [*i. e.* the face between the forehead and nostril]. The nose is longer in proportion; the upper jaw projects forwards; and, as it were, encloses the nose, which seems flat. The jaw is rounded, making half a sphere, which is completed by the lower jaw. The jaws are narrower from side to side, but the opening of the lips is longer. The chin is rounded off [in the direction backward as it descends].

The head of a monkey is just as if a human head had been pressed, between the basis and upper part of the os frontis. It would, in that case, be squeezed out backward and also at the mouth; but as this would increase the length of the head, it is as if a semilunar section had been taken off the upper part of the head, and another smaller section off the occiput,—the vertex being left entire, which would become more pointed, and the alveolar processes being allowed to push forward.

The penis is not so detached from the body when flaccid, and throws itself more into a serpentine course.

The mocock, the mongoose [*Lemur*], and the sagouin [*Hapale*], are not to be reckoned in with the monkey-tribe; they have more of the quadruped in them than the monkey in general has, but are very near the monkey in many respects. They have the agility and manners of the monkey.

The next animal to the Human, after the monkey and mocock, in the shape of body, is the bear; and his actions, of course, are equally near: but he is not equally near in every part. His greatest likeness is in the four extremities; the head and trunk are not much (if any) nearer to the Human than a lion's or dog's.

Beasts have oftener stones or gravel in the pelvis of the kidney than the human subject has; but they very seldom have them in the bladder. This must arise from the horizontal position of the body not allowing the urine so free a passage into the bladder as in the human.

Comparative Observations between the Human and Brute kind.

The contents of the human pelvis adhere to the sides by a much greater extent of surface than in any other animal. The intention of this is perhaps to prevent a protrusion of these parts from the weight of the viscera above, in the erect position of man.

What may be called the 'contents of the pelvis' in the human are not the same as in other animals. The [pelvic] contents in the human are, the urinary bladder and its appendages; the uterus, vagina, and their appendages; the vesiculæ seminales, the rectum, the sigmoid flexure of the colon, and the lower part of the ilium. But, in the brute, the two last are never in the pelvis; and the funduses of the former [uterus, bladder] are in the abdomen. In the human fœtus, however, it is as in the brute.

The cheek-bones in the human race appear to be the last parts of the face that change. Every other part of the face shall be modelled or softened down to the true European type, while the cheek-bones shall continue high.

The human is probably the largest animal which has a clavicle[1]. Those quadrupeds [possessing the bone] are much smaller. It would appear that the feet of the larger quadrupeds are only for progressive motion and fighting. For progressive motion a clavicle was unnecessary, and their motion of fighting is very confined; but, in most of the smaller quadrupeds the fore feet serve as a kind of hands, and are used in a variety of ways, as catching food, assisting in the division of that food; climbing, fighting, &c.

The human is the best-grown animal of any when he is shedding his teeth.

Observations in Natural History.

The Uses of Animals to Man.

Large animals are employed in our service through the whole of their life; some for work, as horses; others for their produce, as cows for milk, and sheep for wool: so that we rob them of their whole labour

[1] [He is the largest existing claviculate animal: the extinct Megatherium, through whose pelvis a man might creep, had complete clavicles.]

either in one way or other. But, in recompense, we support them; so that they do not provide for themselves in any shape, either in food, lodging, or other needfuls in the economy of life.

In smaller animals, viz. insects, we seem to reap small advantage from their labours, except we destroy their means of life, viz. their subsistence: therefore, we are at no pains to support them; and their whole labour is to provide for or support themselves, both in food, lodging, keeping themselves clean, and a number of small economical practices. When they are of service to us, we either kill and use them, or we rob them of their magazines.

We see, then, what a difference there is in the disposition of these two sizes or kinds of useful animals; one kind never provides for the manner of living and futurity, the other does; and, therefore, it is more like the human kind in this action.

Animals in general may be supposed to be useful or hurtful in proportion to their size: however, there may be exceptions to this. If it be generally true, we may judge of any animal's use comparatively. This is the reason why the large animals are made generally to live upon the less; and is the reason why we cultivate the largest of the useful, and destroy the largest of the hurtful. It would seem strange that any should be hurtful; but, if we consider things rightly, we shall find that it arises only from [or relates to] human government, not from natural government; and is therefore made to answer the present system of the cultivated part of the world; but none would be hurtful in a natural state of the world.

It was necessary that many animals should be made to prey upon others; else we should be overstocked with the smaller; for it would be too much for the human race to attend to the proportions that animals ought to bear to one another. It would, from this, seem strange too that nature should make them [the smaller] so prolific; but this was necessary to supply immediate wants. As we must suppose that they are all useful, supposing the use of every one is not known, yet many seem to be useless, and indeed are so in certain governments, and may be so in every one; and are only to be considered as the correctors of quantity of others that are useful both in a natural and artificial state; which circumstance gives us the use of the others. In many governments some animals are absolutely useless; but this arises from the human kind doing what those animals did [in a natural state].

In Britain wolves are of no service at present; but they would be of great service if the land was not inhabited; for then the land would be overrun with such animals as wolves live upon, which increase would be a cause for those animals starving. Therefore, when parts of the world are left to themselves, independently of human policy, there is an equilibrium kept up among the animals by themselves. But this natural government does not concern the human; and, as no use arises from it [to man], it rather becomes matter of curiosity to consider it. But, to make this natural disposition of animals subservient to human society, we are to consider only those animals that destroy other animals that are hurtful to that society and are of no hurt themselves; or, at least, [if the animals so destroyed are not hurtful, yet] the good that arises from them is more than the evil.

It is very remarkable that this [relation] has been so little attended to, as very great advantages would arise from it; and it is still more remarkable that those animals that are of most use in this respect [in destroying other animals] are some of the most inoffensive, and yet are supposed to be the most offensive and are the most dreaded by the people in general.

Natural historians are more pleased if they can class an animal, than they would be if they could show any use such animal could be to society. Indeed all philosophy would be of much more use than it is at present if it was adapted to common life: but this is letting themselves [the philosophers] too low; therefore they must seem learned by some jargon or other. I shall here keep as free of that as possible, and adapt this [Essay] to the ignorant, or rather to those that have an opportunity of applying it to practice.

The animals that I shall talk of are of the Insectivorous and Vermivorous kinds; viz. the snake, the viper, the lizard, the hedgehog, the frog, the toad, the mole, and the bat. These animals live entirely upon worms, snails, beetles, flies, butterflies, both in their grub- and fly-state, spiders, grasshoppers, ants, locusts, mice. Now, few of these creatures are of any use that we know of; but we shall suppose that they are of use: yet, from our first observation we must suppose that they are not of so much use as harm if left to themselves; or, in other words, as the use arising to the others in destroying them [*i. e.* of no other use than as prey to their destroyers]: else we must be obliged to suppose the others [destroyers] to be of no use.

Many worms seem to live upon earth; but that is of its fattest parts: for, we find them most plentiful in fat ground; and, indeed, we might reasonably suppose so. As most animals naturally take that which is most substantial, what service they (worms) can be of in living upon earth I cannot say; but we at once see the hurt that must arise from it. Gardeners suppose them hurtful, which is the reason of their destroying them. Snails would seem to be more hurtful than worms; for, though they do not eat the fat of the earth which is to produce vegetables, yet they eat the vegetables when grown. Gardeners find the inconveniency of this; for they find the young pease and beans eaten as they rise, young cabbages with other plants, also the leaves of trees, and the fruit when ripe.

The natural history of beetles I do not so much know, but should suppose that they live upon smaller insects, as I know that some of them live upon flesh, such as cockroaches [which, however, are not beetles, though commonly so called].

Flies are known to be very hurtful, besides being very troublesome. They spoil meat by blowing it, fruit, &c.; and are very troublesome in this fly-state.

Butterflies are very hurtful when in their grub-state: they eat the leaves of trees; also of cabbages and other greens.

Spiders are not so hurtful; indeed, in one sense, they are useful, as they live upon flies: but they are very nasty in forming webs in rooms, &c. However, the good I think arising from them is more than the inconveniency; but, as some of our animals live upon others as well as spiders, we must let them be destroyed; for of two "goods" choose the "greatest."

Grasshoppers. Their natural history I do not know; but, as they are something like the locust, I should suppose that they live like them. There is a kind of them (crickets) about bakers' shops, that live upon the flour.

Ants live mostly upon corn, but they also eat meat.

Locusts live upon greens, as we hear of their destroying whole fields of corn; but, I should suppose, when green.

Mice. We all know their natural history.

Now it will be necessary to adapt each animal to its proper food, which will show the most useful animals, and at the same time will lead us to keep or destroy them as we find occasion for them.

The snake and the viper I believe feed alike, and I believe they live mostly upon land-mice. Lizards live upon snails, worms, flies, beetles, and spiders. Hedgehogs live upon mice, frogs, &c. Frogs live upon worms, beetles, grasshoppers, butterflies, both in their grub- and fly-state; besides, they keep water clean of smaller animals. The Belleisle[1] green frog [*Rana arborea*] is of great service, as it lives principally in trees upon insects, &c., while in their grub-state. Toads: their natural history is much like the frogs. Moles live upon worms principally. Bats live principally upon night-flies.

Many animals, besides these mentioned, are of vast importance in

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[1] [Hunter was at the siege of Belleisle, in 1761.]

killing animals that are hurtful; but they are such as are agreeable to people in general, therefore are allowed to live. Such are the swallow, the owl, all the smaller birds that live upon worms, such as larks,—indeed all those of the spear-bill class. Now these animals have nothing in them that is disagreeable to the sight. Indeed many, I think, of our first class [mole, hedgehog, &c.] are agreeable: but anything that is disagreeable in them is from a notion that they are hurtful. The viper indeed is so; but, I believe, seldom save when they are meddled with. However, we could dispense with the vipers if all the others were saved; indeed, not only saved, but cultivated. Instead of rewards offered by every parish to those that bring such and such beasts, rewards should be offered to those that form places of residence for them. The notion that hedgehogs eat fruit and suck cows is entirely without foundation[1].

Many of the above-mentioned [insectivorous] animals would be of vast importance in gardens; such as the lizards, frogs, especially the green frog, the [harmless] snakes, and hedgehogs: the mole might be hurtful by forming mole-hills. Hedgehogs have been found of great service in magazines in devouring the mice.

The mole, the shrew, the hedgehog, &c., although animals of prey, or living upon other animals, yet are not animals of offence or defence: they do not attack any animal that can make resistance.

Of the Sociability of Man and of Animals.

The mixing [or associating together] the different tribes of men is much more difficult than that of other animals. Men's minds are linked together by a much greater variety of circumstances than other animals are: men become attached to systems, to peculiarities; and, in proportion to the attachment to their own, they despise those of others. Animals confine their connexions to acquaintance only.

The instinctive principle in animals to associate with each other may be classed under the following heads, each head having its degree of power; viz. acquaintance simply, tribe, genus, species, sex, and, last of all, family [in the sense in which we use the term in common life, meaning the parents and offspring]. However, I believe the instinctive principle of family to associate beyond the first, or acquaintance, is only in those cases where the family is large, more especially where each is

[1] [Except the necessity that cow-boys, &c. have to account for the empty udder. The slaves of Virginia charge the absence of the looked-for supply, when the cows are driven home to be milked, upon the snakes.]

to assist in the economy of the family; this will include the human kind, common bee, humble bee, hornet, wasp, &c.

This instinctive principle of 'family' is that only which I shall here notice. It is in such of the bee-tribe as form large colonies; *e.g.* the humble bee, wasp, hornet, and common bee. They will not allow their own species to pay them a visit; therefore, will not become an acquaintance. This I saw strongly marked in the wasp. I had at one time, three wasps' nests with the wasps alive; some in the chrysalis state, as also maggots and eggs: they were kept under glass covers.

These hives I shall call *first, second,* and *third.* I took two portions of hive No. 1, and I put under a glass a portion which consisted of one tier of cells, with eggs, maggots, and chrysalises, and about half a dozen wasps. The other portion of the same nest, consisting also of chrysalises, maggots, and eggs, was put under another glass. I put under each glass some food, which was for the young as they came out of the chrysalis state, and also for those six wasps to feed the maggots of the tier they had to take care of. This they did very attentively; and the chrysalises, as they hatched, soon took upon them to assist in the duty of the family.

I, one day, put under this glass shade a wasp some days hatched, belonging to hive No. 2, which was immediately attacked by the wasps of No. 1, and killed. I put into the same glass three wasps of hive No. 3, which they also killed. These had one wing clipped, to know them by. It struck me, as they did not destroy the chrysalises of the comb they had the care of, as they came forth, that they probably might not destroy those that had come forth of their own nest under the other shade, which had been above eight days separated from them. I, therefore, took one of the wasps of the other portion and put it under the shade [covering the first portion]; and upon its being put in they immediately assembled about it, some laying hold of a leg, &c.; but they soon let it go, becoming reconciled to it; and, in a few hours, I found this wasp feeding the maggots of this tier. From these experiments it would appear that wasps by some instinctive principle know their own relations.

Here, then, was the sixth cause of association, or that of family, strongly marked. These experiments I carried still further, to see how far I could make wasps of different hives associate with one another by stealing slowly upon their instinctive principles. I took three pieces of comb of hive No. 2, with maggots in each piece, and covered each with a glass shade, numbering them 1, 2, and 3. To No. 1, as a standard, I put some of their own workers, the old queen and a young one. These fed their maggots without interruption. To No. 2 I put workers and two queens, from hive No. 1, to see if they would feed the maggots of hive No 2, which the workers readily did. There was no difference between these and the first. To the third piece of comb I put two queens of the same hive and workers of the hives Nos. 1 and 3, in equal numbers ; so that there were young queens of hive No. 2 with labourers of hives Nos. 1 and 3. For the first day they were very restless, and a good deal of fighting took place; but they afterwards settled and assisted in feeding the maggots. Here, then, the maggots became the bond of union between the labourers of the two hives. They united, contrary to their instinctive principles, to relieve the distressed.

This instinctive principle to associate is natural to all animals, but is much stronger in some than in others: and, when increased by acquaintance, it becomes stronger; and, indeed, so much so, as to appear at first view rather an acquired principle: for, the natural bent of strangers, even of the same species, is to quarrel and fight; but then they associate afterwards. However, I believe that it is not so much the natural disposition in every species, except [it be] excited by some circumstance, viz. towards a stranger.

A hornet, bee, wasp, &c., will fight any animal (perhaps those of their own species more readily) that may intrude on their domestic concerns; but they will not pay attention to one another, when they meet on the same flower, on a ripe peach, &c.

The same principle exists in the Human race; Men have their degrees of attraction towards each other according as they are circumstanced in life. In close connexions he is sociable, excepting interests clash (in which case no animal is sociable). In the crowd he forms his likings, dislikings, and indifferences. But, take him to Siberia, and let him meet the man he most disliked in his own country; he will immediately become sociable with that man. He is, in such a situation, deprived of the acquired cause of sociability, viz. acquaintance; and he feels the want of such: so that the moment the object of acquaintance presents himself, he associates with him; for the dislike arose from having had great choice. This becomes exactly similar to an appetite. A man, in the midst of a great variety of foods, forms his likings and dislikings, which arises from having choice; but, take away that choice, and let him have new kinds of foods which his appetite does not associate with, he will immediately take to the old food he had been in some degree accustomed to, but which he had disliked.

Upon this principle, animals may be made to associate that otherwise would not. Thus if we wish a strange animal to associate with others accustomed to a place, take the whole into a strange place, and let them all stay there but one day; and then bring them home, and they will all seem as well acquainted as if they had been brought up together.

A gentleman gave me a lamb with three legs, which my other sheep had nearly killed; and, after repeated trials, the farmer put it into a house. I ordered the whole flock to be driven to a strange field which they had never been in before; and, the moment they were out of their own territories, they allowed the lamb to herd with them; and, when brought home in the evening to the old field, they took no more notice of it, at least by way of hostility.

I may be allowed to observe that these properties are not in a regular progression, as here set down, in every animal: some having one or two of those principles much stronger than others, and the first acquaintance, which is rather an acquired property and which is often very strong, is the most uncertain; some species acquiring it very readily and strongly, which becomes tho basis of domesticating animals; others having hardly any disposition of that kind, as *e.g.* the fox. Probably all those animals which live entirely upon animal food have the disposition of association least; and this may be necessary in them, as they may be said to be at war with every other animal, and even shy of their own species through selfishness.

Animals have a degree of sociability in them. They generally choose to reside in one place and herd together if allowed. Thus magpies will always stay about one place and build their nest in the same tree every year, even if they should be disturbed. It is very likely that this last is the case with birds of passage. Dogs go together, &c.; but they differ in degrees of sociability, some kinds having it more than others. The more they are so, the more sensible they are, or capable of being taught: they are more capable of associating their ideas than the others are. Hawks and cats have least of this desire of a social life, and are the most stubborn creatures to be taught any art. Men, monkeys, parrots, crows, jackdaws, starlings, &c., always herd together, and are the most sociable animals we know of: they have all more or less memory, [association of] ideas, and reflection.

This property of sociability in animals has its gradations. The strongest is a species to itself, i. e. of any one of a species to another of the same species. Where the second is I do not well know; I should suppose, with some other species that has the nearest relation to it, as a crow with a jackdaw. But a horse seems to have little sociability with an ass.

If animals in a state of nature herd together, they may, I imagine, be domesticated, and *vice versâ*. Thus wolves, or the natural dog, go in herds; goats, sheep, black cattle, horses, pigeons, crows, starlings, ducks, fowls, guinea-fowls. As a proof of this, those that do not go in herds or flocks will not be domesticated: thus, although the wolf may be domesticated, the fox will not; although the pigeon may be domesticated, the dove will not. However, I do not know if this is a universal principle; for many insects herd, as locusts, cockchafers, &c., which shows, probably, that simply herding with each other is not enough, although it may be essentially necessary.

Manners of Young Animals influenced by the Parents.

Young animals take much of their manners from their parents. If the parent is perfectly tame and familiar with Man, the young are never allowed to have any suspicions; for, then, they are taught on all sides. But, if the parent has any degree of shyness, although the young are placed exactly in the same situation respecting Man as the others, yet they will acquire a degree of wildness, exactly similar to the parent. Thus the three-parts jackall could never be tamed in a greater degree than the mother; for, although they were very tame when very young; yet, when they began to understand the mother, they became more wild and could hardly be tamed afterwards. But one that was taken from her early, retained its tameness. The half-bred wolves were very tame, from the bitch-mother being so.

Mr. Walsh informed me of wolves being in the East Indies: he has seen them and shot them. We know there are jackalls. He says the wolves pair; and that the male and female together take care of the same brood or litter.

Of the Natural Disposition of Animals towards one another.

The natural disposition of animals towards their fellow species or genus, when divested of all [superinduced] habit, is the desire of destroying one another; not by way of prey, but through desire of superiority; or, as if in support of some hereditary right. This is a principle seemingly implanted in all the common animals that we are acquainted with. However, some have it much stronger than others; and it belongs much more to the males than the females. It does not belong more to those animals which devour or eat other animals or flesh, than to those which do not.

This, then, is the first principle implanted, or the first desire that animals have towards one another, upon the very first sight of any one of their own kind. But, as soon as this superiority is known, they become more sociable for the future; and more so on the side of the victor than of the vanquished. The vanquished would seem to possess an envious fear. However, these principles, on both sides, lessen by the animals being kept together. This principle is greatly lessened by habit; for no animal that comes into the world comes with any other principle than self-preservation. They have neither the desire of offence or defence, but they soon get this; first for defence and then for offence. As they are gradually reduced to a sociable state, in the same degree they lose the other principle; or, perhaps, we should rather say the other principle is not allowed to grow so strong as it otherwise would do; so that they are insensibly deprived of it towards their acquaintances; but they still retain it towards entire strangers, although not so strongly as if they never had been brought up in a social state.

That this principle can be lessened by habit is well known by those who delight in seeing one animal destroy another; for, to bring the animal entirely out of this social habit and allow him to fall into the natural habit, which he will do, they keep their gladiators from the sight of any of their own kind, till they have totally forgot one another or anything like themselves. They go so far as to keep them in the dark, that they may become still more ignorant, and, as it were, astonished, and have no idea left but the present object in question; so that they only seem to have this combative principle left. This is the practice of cockfighters, dogfighters, &c. From habit, then, this disposition lessens, and the effects become less violent; and, when once an animal finds himself conqueror, fear is removed; he finds himself easy and uncontrolable; which, in its turn, produces a benign disposition, and a desire for sociability. Cats, if brought up from their infancy with birds and mice, never once attempt to kill them; I have seen a hawk and a pigeon in one cage. I have likewise seen a tiger, a cat, a dog and a guinea-pig, all lying together in one den.

On the Combative Principle in Animals.

I believe that the animals that are most disposed to fight, are those that are not beasts of prey: therefore, fighting has no tendency towards food. Animals which have the greatest disposition to fight, have it towards their own species, not with others; the dog is a kind of exception.

Animals which are either subject to be pursued or to fight with their hind feet, generally have their eyes placed on the side of the head, and projecting so as to throw the eye backwards. A hare, rabbit, many squirrels, &c., are instances of the first; the horse, deer, &c., are of the second.

The strength of animals of the same species is I believe best known in their fighting; yet, as that depends so much on the strength of mind, and the two not always going together, this does not become an absolute rule: but all this respects voluntary strength only. However, I believe that in some degree, constitutional strength keeps pace with voluntary strength. Thus, the males of any species can commonly beat the females of the same species, which is voluntary: and we find that the constitutional strength of the male is stronger than the female. Then the male grows faster and larger; he is earlier for the female than she is for him: but, the difference in strength of constitution is, perhaps, best measured in the growth of transplanted parts; viz. between the spurs of a cock and those of a hen.

We know that the spur, or what may be called the rudiment of a spur, in a hen, remains the same through life, only growing in proportion to the size of the animal, like any other part: but, the spur of a cock does more; it shoots out at a certain period of life and grows much faster than any other part.

To know what this difference was owing to, whether it was not the nature of a hen's spur to grow at all, or whether the hen had not that vigour of constitution requisite to make it grow, I made the following experiments. I removed the spur of a young cock and the spur of a young pullet, and changed the spurs by what is called transplanting them. Each spur united to the parts on which it was placed. Time now could only determine the event. In a few months I found that the spur taken from the pullet [and transplanted on the young cock] began to grow, although not nearly so fast as the spur on the other leg; and in time it became a tolerably sized spur. The cock's spur on the hen's leg did not grow for years, which made me at first suppose that the spur of a cock would not grow on any animal but a cock: nor did they ever grow to that size on the hen that the fellow spur which was allowed to remain on the cock did.

From the above experiment, it would appear that the spurs of hens do not grow because there is not that vigour of circulation, or living powers, in the hen which exists in the cock; but still there is a weakness of growth in the hen's spur itself; for it does not grow upon the cock equal to his own spur. As the weakness of growth of the cock's spur upon the hen may not be attributed to a weakness of power in the hen, nor the weakness of growth of the hen's spur upon the cock be attributed to a weakness in the hen's spur, but to the circumstance of transplanting, independently of everything else, I made the following experiments.

As the comb of a cock appears to have more blood, and of course more vigour, than the leg has, I conceived it to be a proper part to make a comparative experiment with the leg; the more so, since transplanting would be against the experiment, if it had any effect. I took off a cock's spur from one leg and placed it in his comb; and I found that this spur grew much faster than the one left on his leg; indeed, more than twice as fast[1].

From all which, I conclude that the power of growth is equal to the power in the hen herself, and [to the power] which is within the spur; but, when transplanted to a stronger soil, the spur grows equally to the powers of that soil. And this is in some degree reversed in transplanting the spur of a cock upon a hen: for, although the cock's spur has full power of growth within itself, yet as the hen, on which it is transplanted, has not so much power as the cock, it only grows at half the rate it would have grown if it had been left on the cock.

That it requires a certain quantity of powers, in either or both, to make the spur grow, appears from the fact that some hens have their spurs grow pretty considerably; but we may observe that such hens are strong and vigorous, usually coming nearer the cock. They commonly have their combs longer, which I imagine arises from the same cause*. They are more given to fight, often crow, and I believe are bad 'layers;' from all which, it would appear that the true or perfect female character is attended with a degree of weakness, but endowed with health.

Of the Rising of Animals.

All the ruminating class of animals, I believe, when they rise, raise their hind parts, and at the same time get upon their fore knees: this is the first step. Then they raise their hind parts entirely upon their hind feet; then the fore feet are raised, but one before the other.

When they lie down they first get upon the knees of the fore legs; then the hind parts fall down; and then the fore legs are folded in under the body of the animal.

A horse, when he rises, first raises his anterior parts upon his fore feet, the fore legs being then very oblique and the feet under his head: the hind legs are brought alongside his belly and the feet are under him. He then raises at once the hind parts; in which action the fore legs are brought erect, by the whole body being brought forwards upon the feet.

* To know how far the comb of a hen might grow larger on a cock, I transplanted several, but never could get them to attach themselves.

[[1] Hunterian Museum, Pathological Series, Prep. No. 54.]

Animals when very weak, hardly or ever lie down. One might be surprised at it; but it is very evident why it should be so. Because, when very weak, they find great difficulty in rising; almost impossibility. Now this as an idea they cannot possibly have [*i. e.* they cannot be supposed to foreknow their inability to rise]. But, what answers the purpose, or what produces this intended effect, is the difficulty in lying down; which difficulty, of course, keeps them upon their legs; the thing intended. When they can no longer rise it is all over with them.

Loose Notes and Queries on the Limbs of Animals.

Do animals which use their fore legs as arms, clasp their young to their breast, besides those that have their nipples in that situation? Is this [clasping to the breast] an instinctive principle at large, or is it only an instinctive principle arising from the situation of the breasts?

Hares and rabbits never use their hind legs alternately, but always together. This arises from the great disproportion between the length of their fore and hind legs; for the fore legs are only used to catch the body when it falls, but the hind legs are used to give the body the spring forwards.

Progressive Motion of the Newt.

The water-newt lifts its right fore foot, then its left hind foot; after its left fore foot, then its right hind foot.

Animals have numbers of legs in proportion to the length of horizontal body they have to support.

On Horses.

The breeders of horses ought to observe well and early the manner in which colts use their legs, especially their fore legs. If a colt is inclined to go near the ground, he should never be turned out on a smooth common, but on such places as are very rough. This brings him into the habit of raising his feet high. If he is inclined to point his toe down, so as to make him, from that alone, trip, he should be shod early, and the shoes made thick before and thin behind, to give him a habit to raise his toe, as we find that women acquire a habit of lowering their toes by being high shod behind. If he is apt to turn his toes out, he should be early shod, thick on the inside and thin on the out, in one foot, two, or all four feet, if necessary. When a horse is hot and let stand, he should have a cloth thrown over him, which prevents quick evaporation: by which means he does not so readily catch cold, more especially if he has been caught in the rain when warm, for water evaporates faster than sweat.

A horse that has not freedom enough in the joints of the shoulders to allow him to step freely forwards with his fore legs, and therefore puts his foot to the ground before he has made his full step, which makes him kick the earth, never goes down a hill but with difficulty. For his step will be still shorter as his legs are thrown forwards with respect to the line of body, in order that they may be perpendicular with respect to the body, by which means the centre of gravity is supported.

As horses are commonly put to strong exertions, everything that accelerates, retards, or in any degree influences those actions becomes immediately an object to those who are concerned with this animal, either as a matter of profit or amusement. Some horses when pretty hard worked in any way, which always affects the breath, take to what is called roaring, which is a sound in the chest near about where we may suppose the bronchia open into the trachea. What the cause of this is I do not know; it does not seem to produce shortness of breath, nor what is called 'broken-wind;' nor does it obstruct their actions; it is only disagreeable to the ear.

But a very remarkable circumstance attends this complaint, which is, that a 'roarer' cannot be made to cough; the common modes cannot excite coughing. Therefore when a horse cannot be made to cough, a complaint of this kind is to be suspected.

Of the effects that Medicines have upon Horses.

Mr. Hayes[1] gave to a horse of his own, which had a locked jaw, Dover's powders ʒij, Camphor grs. v: the horse sweated very much, but died. Mr. Hayes was of opinion that if he had only given him one drachm, it might have recovered him of his complaint.

Dr. Chadwick told me that he killed a horse in a few minutes by giving a pound of Epsom salts, and that he could not in the least account for his death. This was certainly owing to the solution either getting into the lungs, or stimulating the glottis so much as to hinder anything from passing that way.

I am informed by the farriers, who, when giving drinks to their horses, are first obliged to raise up the horse's mouth so as to allow the drink to descend to the throat, that they are, in general, obliged to let his

[1] [Probably Mr. Hayes the Surgeon, who, conjointly with Hunter, gave an account of the dissection of the eyes of Miss C. Brushby, in the 'Medical Observations and Enquiries,' vol. iii. p. 120, 1767. Pathological Preparations in Spirit, No. 2242.]

head down again that he may swallow it; and they often find that something has happened in this operation, which has distressed the horse much, for before they can give him another they are obliged to let him recover; and some horses are some time before they do recover.

On the Ass.

With respect to this animal I have nothing new to say; since it is in every part of Europe nearly the same in size, colour, and habits of life. In Arabia and Egypt this animal is much larger, fleeter, and more beautiful than in Europe. Its favourite food is the alkaline plants, which are produced in great plenty; and for drink it prefers saline springs to fresh water. This animal suffers great violence on its natural habits in being accustomed to these northern countries.

In the reign of Queen Elizabeth, the breed was extinct in this kingdom; and, to this day, in Norway and Sweden, an ass is never seen but as a curiosity in the stables of the great.

Economy of Crows[1].

The male and female both sit upon the eggs; probably the female by day and the male by night; for the male appears to be the one that goes in quest of food and feeds the female; probably while she is sitting; but he certainly feeds her after the young ones are hatched. When the young ones are hatched, the female sits upon them, and the male goes in quest of food for the whole family. When he comes home she leaves the nest, sitting either on its edge or on a neighbouring bough, and flutters her wings for food to give the young ones, like a young one that has just flown; and he gives her some, but appears to give no more than what she takes for herself. Then they both go to the side of the nest and feed the young, who stretch up their necks with open mouths. They seem to put it pretty far down the young one's throat. If the quantity the male has to give is in small portions, as worms, &c., he seems to give, from his throat, each his share, and then flies away for more. If the portion of food be too large for any one young one, the parents both tear it to pieces, and then feed the young with it.

If the male is long in any of his returns, the female seems impatient and sets off either for herself or for her young ones. They bring the meat in their throats, which makes a considerable lump at the root of the lower jaw.

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[1] [As Hunter's observations relate exclusively to the *Corvus frugilegus*, the common name of that social species will be substituted for the term now usually applied to the solitary *Corvus corone.*]

It is curious to see how the female is employed while the male is abroad; especially when the young are very young. She sits occasionally on them; but occasionally goes off and looks over the nest, removes any excrements and cleans their feathers; for, at an early period, the young are not able to throw their dung over the nest. The mark of distinction between the male and female is the voice. The one that stays at home has by much the softest voice.

When we examine Nature in her operations in things that have an affinity, we find this affinity not only in one thing but in many, if not (in a less degree) in all. Let us take the rook, for example, and see how far in their economy they have not a very near affinity to the human kind; however, so far only as their instinctive principles are allowed to act.

Rooks are instinctively social animals: they herd together, have their distinct colonies or villages; and the only distinction betwixt the economy of the rook with her house and the human is, that the rook only uses it in the breeding season, having no other use for it.

Rooks not only associate with one another, but they in some degree associate with Man. They often build their villages near or in towns or villages.

Economy of Humble-bees.

This insect is a striking instance of the union of the different parts of nature with each other, each part acting immediately for itself, yet collecting for others, and each depending on another, making in the whole one uniform machine, although made up of many and various parts.

An early spring brings forth a vast variety of things upon which there is a vast variety of animals to live: it brings forth flowers, it also brings forth the humble-bee, &c.

The history of this bee [*Bombus terrestris*] does not interest us nearly so much as that of the common bee[1] [*Apis mellifica*], neither as to curiosity nor profit: therefore it is not necessary to be so circumstantial in the facts; for the humble-bee does not deserve the admiration (when known) that we would naturally bestow upon it from a slight acquaintance; for there are some things we should suppose belong to its labours which in reality do not.

I imagine it is not so universal as the common bee, for it is not worth cultivating or transporting from one country to another. They have the same bee in Newfoundland, both the dark cross striped with brown,

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[1] [See 'Observations on Bees,' Animal Economy, p. 422.]

and the brown; and therefore it is probably a bee of a cold climate rather than of a warm one[1]. They propagate there in the same manner as they do in Britain.

This genus* is the largest in size of the bee-tribe in this country; and probably every country may have its humble-bee, and it may also be the largest in that country. They are male and female. The females are of two kinds: viz. queens which are annual, and labourers which are semi-annual, and which breed along with the queens, which is of course in the same year in which they are themselves bred; this I believe not to be the case with the queens, they being bred themselves too late to breed the same year.

They come nearer to the species of the common bee than to any of the others, considering the bee as a tribe, being composed of queen, male, and labourers; but there appears to be a gradation in this tribe of insects, one leading into the other. Although there are bees whose size and shape entitle them to the term of humble-bees, yet I shall consider none under this term but those which form a family, all the others coming under the appellation of "solitary bees." There are different species which go by the name of humble-bees. The distinctions which would make us suppose there were different species are their size and colour, with a difference in the length of tongue or proboscis, but probably the colour is mostly to be depended upon. But this question of species is to be determined with certainty, every bee in a hive being of the same species, although we shall find great variety in size in the same hive, but then not in colour, shape, and length of proboscis. I believe the humble-bee has the longest proboscis of any of the bee-tribe, by which it can suck the honey from flowers whose cups are deep.

In a hive consisting of 157 female humble-bees, their proboscides were nearly all of a length, proportioned all to their size, but not of a very long kind. Long and short proboscides are common to both female and male; but I should suppose that the female of any one species has a longer proboscis than the male of the same species; for in the above hive, where there were only twenty-one males, the proboscides of these males

* I conceive this bee forms a genus even in this country: if they are all one species, then there are some varieties; but this I doubt, for no one hive has any variety, yet I could conceive that the Dun might be a variety. [Latreille has sanctioned the correctness of this opinion of Hunter's by the formation of a distinct genus (*Bombus*, Latreille) for the reception of the different species of humble-bee.]

[1] [This conjecture has been subsequently confirmed by the capture of a species of humble-bee in the most northerly latitudes yet visited by arctic voyagers.—See Kirby's Description of the Insects collected in Captain Parry's Northern Expedition.]

were shorter, especially the sucker. The proboscis has a sort of fold-joint at the head, by which it can be considerably lengthened. It is the females, as also the female workers, similar to all the females of the bee-tribe, only that have stings, none of the males having any; and as it is the females only that are employed in the œconomy of the hive, it is only these that are furnished with weapons.

The humble-bee is more a defensive than an offensive animal. I believe they seldom attack, only sting when laid hold of; and their sting has very little effect either as to sensation or swelling. When attacked they throw themselves on their back by first raising one side, and also raising the legs of that side, and then they tumble over. They are very hardy, and labour in weather that the common bee will not go abroad in, and this is owing to their having but little store, and their heat much less than that of the common bee; and for the same reason they work much better in the evening than the common bee does, but not near so late as either the hornet or wasp; for they are not in constant employ in finding food for their young, as the young feed themselves, and they have store for immediate use for themselves and the young bees as they hatch. They will not admit of being removed from their first situation to another; for when removed with the whole hive, as also with all the bees, and confined under a shade for some days with their cells filled with honey-food, they gradually leave it, but do not seem to go back to their former situation, if it is distant half a mile; from which circumstance, and from all the labourers dying, and the queen leaving the hive in the winter, they are not capable of being domesticated. They are not fond of having their hives meddled with or disturbed; for then they appear to get lazy, and do not breed so fast, their combs or cells not answering any future purpose, not being what I have called 'the furniture of the hive,' as in the common bee. From these circumstances they are much more liable to accident, as also from their mode of forming their hives, which is liable to many accidents.

A wet season shall drown many hives, by [their] being begun by a single bee, which is the mother of the colony, and which at first labours abroad; but if killed, which is often the case, the whole falls.

It would appear that they are attacked by their own species; for in the place where I enticed them to build their hives I have found another queen dead, which I supposed to have come there to take possession, but to have been killed by the other queen and her offspring or labourers, who then were but few, being only two or three. They collect honey for store, but it is not of such extensive use as that of the common bee, although for a time answering the same purpose.

A family is first begun by a simple female, not colonizing like the common bee, but she is afterwards assisted by her own offspring. She is very sparing of her labour, as also of that of those which she breeds; for I believe she never makes any provision to have her hive formed, but in making it often chooses some accidental place, as a mouse's nest; and, although we find cells, yet these are not formed by her, but only by the maggot going into the chrysalis state; so that they appear to have been more busy than what they really are, for the whole of the cells are formed by the young maggot-bees; the queen's whole labour is the formation of one cell of wax, bringing in farina, and laying eggs.

It is to be remarked, that when I speak of *they* or *them*, I mean principally the labourers, although the queens may often be included, more especially at first, when she is beginning to form her colony, but never the males; for the variety in the actions of the humble-bee, or the œconomy of the hive, belongs chiefly to the labourers.

There are two periods where we may begin the history of the humble-bee: viz. either in the autumn, when the female is copulating, just before she goes into winter-quarters; or in the beginning of summer, when she comes out to propagate, which last is the only time that can be called a beginning of their history, as the going into winter-quarters is only a simple act of a young queen bee, but which I shall begin with, because it leads to the coming forth in the spring. We shall find that the labourers are capable of breeding the same season, which produces a variety, as also an irregularity in the history of this bee.

Of the Winter Habitation of the Queen.—None but the young queens live through the winter: they leave their hives, and go into such places as instinct directs them to; but as those places are what may be called hiding-places, they are not easily detected. Not finding any on the taking down of old houses, nor in the removal of old brick walls, nor being informed by carpenters and bricklayers in the country that they ever observed any, I gave orders to my gardener to observe, whenever he took down any bank or dug up any old dry ground, to have an eye on this subject; and two humble-bees having been found in the winter in the bank of a haw-haw, therefore I conceive a certain degree of moisture is necessary for their preservation. Their holes are, I believe, such as have been made by moles, and probably shrews and land-mice. It would appear they go to them at once; for we do not find humble-bees flying about in autumn in search of such a place, as we find them in the beginning of summer in search of holes to form their hives in,—a sleeping-place in the winter requiring less of everything than a place for the hive in the summer, although there are at this season fifty queens going into winter-quarters for one that comes out.

According to the state of the weather in the autumn they go sooner or later into their winter-quarters; but if the autumn is cold and wet, we find no humble-bees flying about in the latter end of September. In the autumn of 1791 I found the humble-bee but little abroad; and on the 28th of August, in digging a bank, we found a large humble-bee about a foot beyond the surface of the declivity. It appeared at first dull and inactive, but when held in the hand and was warmed, it flew away. The weather had been showery, cold and windy for some time. I conclude that this bee had taken up its winter residence, for it could not have any home to go to. They remain in those places through the winter; but most probably not one in a hundred live through the winter, especially if the season is either severe or wet.

Of the Time when they come forth.—They continue in their winter-quarters till the weather becomes warm, which is in the spring; however, they sometimes come forth in good weather in the winter, but go to rest again most probably when the evening grows cold. About the beginning of January 1787 a humble-bee was found in the grass very weak; it was brought in and put under a cover, but it died. On the 15th of the same month another was picked up, which was a large queen, and very lively; that was also put under a cover, but it slowly became weaker, and on the 20th of February it died; it had no fat in its belly. It is probable that those that came forth so early had not provided for themselves sufficiently in the autumn with a store of fat, and were obliged to come forth in hopes of food. In March I found a humble-bee in a forcing-house, on the flower of a Persian lilac; it had come in at one of the windows, and was probably drawn there by the scent of the flowers. It was a large female or queen. It had a quantity of granulated fat in the abdomen, but not so oily as in the autumn. About the middle of April, when the apricot and peach blooms are come forth, then we find humble-bees; but this depends on the season, for in the spring of 1790, after a very mild winter, as also a mild spring, when the apricot and peach blossoms were blown before the middle of March, we then had the humble-bees flying abroad. About the latter end of March or beginning of April the humble-bee is seen flying about. At this early season we find them on the blossoms of trees, &c., but only sucking for their immediate food, as they have not yet fixed on places for their hives. At about the beginning of May they fly about, and near to the ground, then lighting upon it, creeping upon the earth, and going into the holes of walls: these are in search of proper places for their summer residences for propagation. Such bees are all females, and of the largest size, but they do not seem to be at this time ready for propagation, for we seldom find any hives till May.

In their times of propagation they are not so regular as the common bee, for they cannot begin till the season will allow, having no provision in store. I found in the summer of 1791 some young humble-bees abroad about the beginning of June, viz. small ones; and after this period we seldom find the first or large queens abroad, and when they do come out, I suspect that they have been disturbed or have had their first hives destroyed, and that they are beginning anew.

Of the Situation of their Hives.—Their hives are found in various situations. They are in holes in the earth, especially in dry banks, in holes in walls, in thatch, in hay, in dry dung on the ground, at the roots of grass, in meadows, in trees, in an old nest of some bird, in a laurel-bush.

The same species will build either in grass or under ground, for I have found the queens in both, as also in dung. In whatever situation they choose, they are commonly led there by some other circumstance than simply situation, or else probably situation would be attended with less variety; but it seems to be more the materials of the nest that induce them, than this or that situation; for often, or almost always, when they can, they build their first or honeycomb in an old mouse's nest. What makes me suspect this, is the similarity of the materials between their hives and a mouse's nest; and a servant, who had orders from me to preserve every mouse's nest as well as humble-bee hives when mowing, found a mouse's nest in the meadows, and upon opening the moss, dried grass, &c., he found five young naked mice, and with them a humble-bee, which immediately flew away: this was in the month of June. This bee most probably would have put up here if there had been no mice; or if they had been further advanced, she might have made them leave their quarters. I have found them in a rat's nest under ground*.

Upon this principle I made several experiments to entice them to certain places, in which I succeeded. For instance, on the 4th of June, I dug small cells or cavities in the ground, and bored a hole aslant into each of sufficient size for a bee to enter. Into these cavities I put some fine soft hay, and covered the cavities over with a flat stone or tile; I found humble-bee hives in several of these, for I had only to raise the stone or tile and examine the hay. The first thing I observed in those cavities where breeding was going on, was, that the hay where the bees had taken possession was perfectly dry, while in the others it was

* Although the humble-bees would appear of all the bee-tribe to be the greatest slovens in their mode of propagation, yet most probably, like most slovens, they take more pains on the whole than many of the others. The regular and methodical way in which the common bee, the wasp, and the hornet begin their hives, appears to give but little trouble afterwards. There seems in the humble-bee much more left to the instinctive principle, as they go on, either of the young or the mother, than in the above-mentioned species.

mouldy. A hole was to be observed either at the top or at one side, leading into the centre of the hay; the hay itself surrounding this hole was more regular, and as if turned round the hole; and this kind of regularity was carried down some way where the cell was formed, for honey-storing and breeding were begun. As this hay had been put in irregularly, the bee must have produced this regularity; and, I imagine, by twisting herself round and round, so as to give the hay for a little space round her this circular form. By this contrivance I could at any time examine their progress: but they do not always confine themselves to places where the materials are collected for them; for I am of opinion that they may have the power and disposition to collect materials for themselves.

However, I am apt to think that they are directed to situations by some favourable circumstance; for in one that had built its nest in a laurel-bush, it had been led to this situation by the nest of a bird that had bred there the preceding summer; but the bird's nest was filled with moss, which was carried higher than the brim of the nest, and in the centre of this she (the bee) had deposited the materials and laid her eggs: but the question is, what brought the moss there? I can conceive it possible for this collection of moss to have been the labour of a mouse; and I am inclined to think that they (the bees) may not have the mode of bringing soft materials for the hive; for in some which I found under ground, where the straw had been either very scanty, or none at all, they had covered their work over with a sheet of substance like farina. However they may wish to cover their combs, &c., when exposed, with such soft materials as they can get, yet I do not imagine they bring it from any distance; for I believe they have not the power of carrying it: I rather conceive that they scrape, as it were, what is near them along to the hive; for I have put their comb on the ground with very short grass, and they have with their fore-legs scraped the grass under them, and in this manner they have gone backwards with it towards their hive and covered the hive at last.

In the hives under ground I have observed that they form a covering for the whole. This covering is a very clumsy one, yet formed in some degree similarly to the external covering of the nest of the wasp or hornet; the external surface having a kind of oblique hollows passing upwards, but which do not pass through. However, this covering has several passages through it, through which the bees pass: it is composed, I imagine, of the farina, at least it has the same visible properties. I should suppose the intention of this is to keep out the wet that soaks through the ground; for in such situations they have but little hay or moss. In some nests which I have moved from under ground and placed on a tile, covered with a garden-pot, above ground, just at the opening of the passage by which the bees formerly entered, I have observed them to have covered their comb or cell with a sheet of this substance, and I have found that they have removed it again.

Their nest is always begun by a single female, which was one of the last year's brood, and is inhabited only one season. When the proper place is fixed upon, and the moss or hay (when there is such) is so prepared, as above described, in the centre of which she has formed a small space, or kind of cavity, then into this cavity she first makes a large cell or hollow ball, about the size of a nut (some larger), in which she deposits some honey, and often covers it entirely over[1]. This globe is made of wax, and is, I believe, the only wax she forms. It melts by heat, but is commonly softer than the wax of the common bee; nor is it so white, but appears of a dirty yellow, which I suspect is owing to its being mixed with farina, somewhat similar to what the common bee covers the chrysalis with. This honey would seem to serve the queen as a reservoir or magazine of food, when the weather is too bad for her to go abroad; as also the first brood of bees, when just emerged from their pod, till they are able to go abroad; which pods now become reservoirs for honey for the first brood as they come from the chrysalis state. Having formed the hollow globe, she then begins to breed, and one would suppose to form her comb. She first brings in some farina on her hind-legs, similar to the common bees; but I think she gathers it from a greater variety of flowers, as it is composed of a greater variety of colours and consistence when on her legs. I imagine she mixes it with some juice, for it is more tenacious than simple farina, and is of a dirtier colour. She now deposits it in an irregular square mass a little way from the hollow ball. On this substance she deposits her eggs, one upon another, lying parallel, and then covers the eggs with the same kind of materials, forming a cavity in which they lie. There shall be half a dozen of these eggs or more in this little square. This becomes the basis on which all the future cases are formed. These eggs, so deposited and covered over, hatch, and produce a maggot; but in what time the egg is hatched after being laid I do not exactly know, but I have reason to believe their progress is pretty quick; for in those which I have examined at different times, I found that such as had been laid on the day of examination had large maggots on that day fortnight[2]. When hatched, they leave the soft shell of the egg in the cavity in which they are contained. This surrounding substance is the food of the maggot, as it is of the common

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[1] [Hunt. Prep. No. 3121.]

[2] [Ib. No. 3122.]

bee, only that the present species feed themselves, while the labourers in the common bee feed the maggot. They feed upon the inner side of the surrounding mass, by which means they increase the cavity as they themselves grow; and as they destroy the inside, the old one lays more on the outside, so as to keep them always covered, which both incloses them and serves them for food; and as they grow, this square mass becomes larger, commonly of an inch or more square; so that the humble-bee does not feed her young as the common bee, wasp, and hornet do.

Their growth is pretty quick, for in about two weeks after hatching they are ready to go into the chrysalis state. Like the wasp, hornet, and common bee, their excrement is left in the cell, and dries, which has often the appearance of bee-bread. When pretty large and ready to get into the chrysalis state, they have almost ate up their surrounding materials, which now make a very imperfect covering for them, each maggot being of full size.

They spin themselves a covering, which is at first attached to the inner surface and edges of the holes of this mass, in which I have detected them in all the stages of the formation of the cell, which is similar to the food of other chrysalises; but as there is a series of these cells, and as they afterwards contain honey, they have, I believe, been considered as formed by the old bees for the purpose of breeding. Having now covered themselves over, I believe that the old one, or ones, remove that part of the mass which remained; for the cells become clean on the outside, excepting on the under surface, which forms a union between them, and, I believe, allows the cell afterwards to contain honey the better. This cell is a complete cavity, similar to all that make an entire pod; not similar to the bee, wasp, or hornet, which only line their cell formed by the labourers, and do not line the bottom. These cells form a very regular cylinder, rounded off at each end, and are very strong and thick in their coat. They are united at their bottoms to each other with a brown substance, which, indeed, covers the whole bottom of the cell: in this cell they cast their last maggot-coat, and change into the chrysalis state, placing their head uppermost, and in about eight days they are ready to come forth. Before the bee comes forth from the pod, the queen deposits on the upper surface and towards one edge of this square mass of pods, a mass of farina, in which she lays some eggs, which she covers with the same materials as before. These cells are placed at the beginning parallel to each other pretty regularly, forming the first batch of pods, and are small; but they become more and more irregular as the formation of the mass of cells proceeds. When the chrysalis has formed all the parts belonging to the bee-state, it emerges from this cell or pod, throwing off, or creeping out of the chrysalis coat which covered them in this state. It requires a great deal of labour to get out of the cell; they are obliged to tear and destroy the upper end with their lateral teeth or pincers: we can hear them at work before they have made an opening; and when their heads have got through, but not their body, they work at the edges to enlarge it. As the maggot is constantly enclosed in this mass of farina, it is not so easy to say when it changes into the chrysalis state, but now as it forms a well-formed cell for itself its progress is more detectable. In the common bee, wasp, &c., the change is known by their covering the mouths of their cells; but in the humble-bee they enclose or line the cell of farina. These cells, from whence the young bees have emerged, I have observed become a deposit for honey for the whole hive in wet weather, and for the young bees that are bred in future. As the cells are to contain honey, they are strong and durable in their substance; but that it might retain fluid honey, it is lined with a substance; and to render the honey more secure, they often cover over the mouths of their cells; likewise deepen many by raising their edges with the same kind of substance that forms the first cell or globe.

When the young bee comes from the cell the hair is wet, but it soon dries. Those parts which are (afterwards) of a dun or brown colour, are at this time white, but in a short time they become brown. For some time the young bee seems incapable of flying, and is provided by the mother with honey, which they begin to lap as soon as they emerge from the cell: indeed I have put honey before them when only the head was through, and they have lapped it up: but they are soon able to assist the mother in collecting materials for the further support of the increasing family. The dab of farina, which she placed on one of the edges of the square mass of chrysalis-cells in which she deposited her eggs, is kept increasing as the maggot grows; she goes through the same process as before, forming another batch of cells on this edge, which does not accord with the first mass in regularity in any way.

The queen is now assisted by this her first offspring of labourers: they assist in bringing in honey to fill their own cells from whence they came; they also bring in farina for a new or third offspring, which is placed upon another edge at the top, or on the top of one of the chrysalis-cells into which she deposits her eggs, which goes through all the above-described processes; and, while the chrysalis is completing in the second batch, they are placing their dabs of farina on them for a fourth: and so they go on increasing their number of batches, as also the cells in the same proportion.

This mode of increase of cells by different batches obliges them to be very irregular; for although each batch has a kind of corresponding regularity respecting itself, yet it has none respecting that on which it is placed; so that by the time that they have done breeding, the whole makes a very irregular mass of cells, the first cells being undermost; and as new ones become completed by the successive births, they are neglected, and, from their situation, they are allowed to moulder away, and often they become the nidus for the eggs of flies.

To ascertain with accuracy the circumstances attending their increase, I continued the before-mentioned mode of enticing them to proper places, from which I had an opportunity of examining a great number of hives at different periods from each other, so as to bring out what was going on.

When we observe the progress of the hives only, we find that the first and second tier of chrysalises in their cell are very small, being those of labourers; that the second or third tier are larger, which are principally males; and that the succeeding and upper tier are composed of much larger chrysalises, which are the young queens. The female labourers are of very different sizes; the males are all nearly of the same size, as has been already observed. After the queen has made some progress in the hive, we find two kinds of females with males; therefore there may be said to be in each hive three different kinds of bees, having three periods for their production and lives. The small females and the males are produced first, and the queens last. In the month of June we find nothing but small bees, but in July, especially about the latter end, we find the large chrysalis-pods, and also young queens.

I before observed that the hay, moss, &c. placed to attract the humble-bees was dryer than the hay in similar situations without the bees; this is owing to a greater degree of heat in this inhabited place than the heat of the part abstracted from them. I found the difference near twenty degrees. We may observe, that no insects inhabit such nests; the place shall be surrounded with ants, grubs, &c., but none go among the hay or cells; but the moment such a nest is forsaken, the honey, maggots, or chrysalises are immediately devoured.

Of the Food of the Maggot Humble-bee.—It must have appeared, from what has been already said respecting the progress of propagation, that the farina of plants, which they bring in on their legs, is the food of the maggot, for I have found it in the stomach of the maggot; but it often seems to differ from that on the legs in consistence, although I have found it in some the same to appearance, being very different in different bees as they are collecting it. It does not dry as the farina does, but keeps nearly of the same moisture, similar to the bee-bread. Probably they mix it with some juice that does not dry readily; or, to prevent its drying, it is possible they may mix it with the juice of some other plants which does not dry; for instance, the inspissated juices of the leek and onion do not dry.

I took some of the materials that enclosed the maggot, and some of the matter from a humble-bee's leg, and put them on a piece of clean white paper, and burnt them to see if they melted, and all smelt alike: the materials from the humble-bee maggot melted a little, and burnt, and gave a pretty sensible smell; that from the leg of the humble-bee much the same, only it did not smell so strong; but their scents were the same in quality although not in quantity. This substance is both their food and their covering.

To see if there could be extracted anything like wax, or even oil, I boiled a very large hive, and got a very small quantity of a substance that floated on the water; and when I had dried it, it hardly melted, although it did in a small degree, and burnt pretty clear, by leaving a tolerably large cinder; but I conceived it had [wax].

In one of my places which I made to entice a female to begin her colony, after she had formed her hive and bred several small bees, I took from them the whole comb to see if they would set about a new hive, which they did: but on examining it on the 12th of August, I was astonished to find there were no young females, only the large queen and labourers, nor were there any large cells containing large bees in the chrysalis state. I examined the hive again on the 8th of September, when I found only one queen, with several labourers and males. All the chrysalises were come forth, and I observed one cell which I conceived had belonged to a young queen. Why she did not breed queens as usual I cannot imagine. The queen was very weak, not able to fly, and died the day after she was taken, which would appear to be much sooner than the queens of former hives died; but when there are many young queens, it is not so easy to ascertain when the old queen dies; and probably this circumstance explains it, and she had lived her natural life. In June I took away from a hive, where there were a good many bees, the last-formed chrysalis-cells, which either contained males or queens, to see if the future were to be all queens; but they appeared to have become lazy.

To ascertain whether any of the labourers or young queens laid eggs, I took the whole hive of bees, and examined their oviducts to see what state they were in, and I found but one queen whose oviducts were full of eggs[1], which made me conclude she was the mother of the whole; all

[1] [Hunt. Prep. No. 2616.]

the other queens having small oviducts and empty, or at least no eggs fit for laying[1]; and I found what I did not expect, viz. that some of the labourers, even the smallest, had their oviducts full of eggs, and others with none. This observation led to the following experiments. I removed the queen after she had bred some labourers and males, and also every maggot and egg that lay on the comb: this being done, I found, in about a week after, dabs of farina with eggs and maggots: these I allowed to remain till about the 8th of August, and upon examination I only found six females and seven males, one of which had just come forth, which males I think were smaller than common. There were no queens bred by the labourers, and I observed that they did not continue the hive equally with those whose queens were left in the hive. There always became fewer and fewer of them till the whole hive was deserted, probably about the time the queen would have begun to breed young queens. This experiment I have repeated, and with the same success.

Of their Copulation.—On the 1st of August, 1789, having before taken a hive with the whole bees and put them under a large glass shade, they went out and into their hives; but one day I saw a large bee on one of the sides of the shade, and another, as it were, standing on its tail with its four feet on the back of the other. Suspecting they were in the act of copulation, I caught them both, and immediately immersed them into spirits[2]. The male did not let go his hold, and they both died in this position. I found the two holders fast on the sides of the beginning of the vagina. The sting of the female was, as it were, projecting between the two: this was at a period when breeding was over; for in this hive there were neither maggots nor eggs, and only a few chrysalises, so that copulation could answer no good purpose for this season, therefore only fitting them for the next. As we never find them copulating abroad like many other insects, it is reasonable to suppose that they copulate at home, and more especially, as they will by this means keep to their own family in their propagation.

About the latter end of August the humble-bees are becoming indolent or inactive, more especially the males. This indolence increases through the month of September, and some way into October, if the weather is tolerable; but by the middle of October there are hardly any to be seen. The males are now many more in number than the labourers, about eight or ten to one. On the 29th of August I caught thirty bees, and only one of them was a labourer. The males about this period get into large flowers, probably for food, such as the flower of the hollyhock; but not

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[1] [Hunt. Prep. No. 2615.] [2] [Hunt. Prep. No. 2852.]

finding much, and the weather becoming cold, and having now hardly any home to go to, they become benumbed and die.

To see what would become of them, if I were to take better care of them than the season now allows, I had caught for me, throughout the month of October, all the humble-bees that could be found: I put them under a large glass, with honey for them to feed upon, which they did, but they all died in the course of some days after being confined. The intention was to see what bees lived through the winter and what not. It was in these trials that I observed the disproportion between males and females: they both died equally fast; and of the females, whether large (which I supposed to have been the last year's) or small, they died equally soon. Most of them died with the proboscis erected or elongated.

Of the Progress of Breeding.—The progress of breeding appears to be in this manner: the first step is the female bee of the last year's brood, which has lain dormant through the winter: she begins the hive; and the first brood are the small bees or labourers, which assist the mother in the labours of the family, bringing in farina for the future maggots, and also probably honey, to fill the pods or cells from whence they come; and, towards the latter end of the season, they even lay eggs. Some males are in the nest to impregnate the breeding labourers[1], and then the young queens are bred. How far labourers are continued to be bred along with the males and young queens I do not yet know, but I believe some are, for I have found small pods or chrysalises along with the large. I have reason to suppose that the males give no assistance to the females in collecting either the farina or honey: I have never been able to detect a male with farina on its legs, although I have examined many hundreds. Nor do I imagine that what are to be the next year's queens give any assistance in the year they are themselves bred in; indeed they are hardly bred early enough to breed much that season.

Economy of Hornets.

The hornet (*Vespa Crabro*) and the wasp (*Vespa vulgaris*) are two species of the bee-tribe, yet they are so much alike that I could almost suppose them the same species. They are much more so than any other two species of the same tribe. They are exactly the same in form, and nearly so in colour; and their anatomical structure, mode of life, food, offence and defence, structure and materials of combs, and

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[1] [Further experiment and observation may be requisite to establish this necessity.]

mode of feeding the young, are nearly the same. This is so much the case that a history of the one would almost answer for the other. The only difference appears to be size, the hornet being by much the largest: the situation of their nests may differ, although that is often the same in both; the hornet commonly building its nest in some dry cavity, as in a summer-house, hollow of a tree, &c., while the wasp commonly builds its nest in the ground; sometimes, however, in the hollow of a tree. Hornets are much fewer in number than wasps, although they appear to breed as many young ones. The only reason I can assign for this difference is that the hornet builds its hive in very conspicuous places, and it is therefore much more readily destroyed than that of the wasp. Or, probably, the winter quarters of the queens are less secure.

Of the Hornet's Hive.—The hive of the hornet is a very regular building; for as they commonly build in an area where there is room, they are not encumbered. It is commonly attached to some surface which composes the ceiling of the area in which they build. The complete structure is a ball nearly round, but rather longer from top to bottom than from side to side; from about 12 to 15 inches in diameter. This ball has not a regular smooth surface, but has a great many openings leading obliquely into it, which pass for several inches between what might be reckoned its different coats, and often terminate in a blind end. A section of the outer coat from top to bottom would almost give the idea of its being built with the wafers made by the confectioners. This mode of building gives thickness to this shell; for from the outside to the inner surface is about an inch and a half; it also gives lightness. The colour of the materials when formed into this shell is a dun or light brown, but not uniformly so; it is a stratum of lighter and darker alternately, and that pretty regularly. This we can hardly suppose to arise from design, yet its regularity gives that idea. It is extremely brittle; it will hardly cut with a pair of scissors without chipping, and when wet, it is like wet paper, but not nearly so tenacious, for it can hardly be kept together.

In this shell are placed horizontal partitions or platforms, one tier above another; or rather, following the order as they build, one tier below another. These platforms are near an inch from each other, but the lowest two or three are rather at a greater distance than the upper. The uppermost is attached to the under surface of the dome: the second is attached to the under surface of the first by columns that suspend rather than support; the composition of which is much stronger than that which either composes the outer shell or the platforms, having probably more animal matter mixed with the old wood. The platforms are of a size answering to their situation in the shell; the largest in the middle answering the largest diameter of the shell and becoming narrower towards the top, as also towards the bottom. These horizontal platforms are composed of combs or cells, distinct in themselves, but each side is common to it and its next cell. Each cell is a kind of cylinder with a mouth and bottom; and the platform is composed of these, being placed nearly parallel to each other, with the mouths on one side, the bottoms on the other; one side making a series of cells, the other making a pretty smooth surface; however, as the bottoms are a little rounded, the surface looks like a pavement.

The mouths of the cells are downward, making a kind of ceiling composed of compartments, and the bottoms of the cells make a floor above. A cell is not a perfect cylinder, but is rather narrower at the bottom, and a little bent, which makes them diverge more and more as they are further from the centre; the centre one being perpendicular, and those on the circumference a little oblique; and also, by their taking a little bend, this curve becomes more and more towards the circumference.

Hornets work day and evening till about eight o'clock, in September; that is, they go out and into their cells till that time, as I was informed by Mr. Eden's gardener; and when I went to take the nest about eight o'clock on the 24th of September, they were then going out, and others coming in. An old stump of an oak-tree, rotten on one side, afforded them plenty of materials for building with, of which they had availed themselves: they were busy, and had carried off a great deal of it. They are not so easily disturbed as bees and are not so ready to make an attack: they are less offensive than the wasp: but this is probably owing to the females only having the power of attack, and seldom leaving the hive or nest.

Hornets are distinct males and females. The females are rather more numerous than the males. There is great variety in the sizes of both males and females; but not so great in the male as in the female. The males in general are, in size, between the largest and smallest of the females: this I apprehend is owing to the largest females having eggs in them, which always increases the size.

Of the Males.—The males may be easily distinguished from the females by several well-marked differences. The first and most conspicuous is the horns [antennæ], which in the males are longer by one half, are thicker, and the first joint from the head is only one-third of the length of that in the female: the circular joints to the end of the horns are as long again as in those of the female. The head is smaller, and on the top of the head there is a black mark resembling a crescent, on which is placed three small eyes at right angles from one another, the point of which being in the middle and fore part of the head, they are not a pin's breadth asunder. The females have the same eyes placed in the same situation, but without the above black mark. The yellow on the head of the male is brighter. The body of the male is shaped very much like the female's, excepting at the point of the abdomen, where the last scale is rounded off; while that in the female is pointed: and in the male the penis may be seen projecting a little. The number of the scales of the abdomen also differs, being seven in number in the male, in the female only six. The colour of the male is not much different from that of the female, excepting that there is not as much of the bright brown on the thorax; nor are the marks on the back anywhere different: but, on the under side of the abdomen, the bright brown marks which are on the middle of each scale are smaller and sharper than in the female, and of course there is more of the bright yellow: the last scale on the belly is much smaller, has very little yellow on it and is blunt, while in the female it is much larger, sharper, and of a brighter yellow, with a small fissure at its point, beyond which the sting and the feelers on each side may be seen projecting a little almost at all times.

Of the Females.—The females differ much more in size than the males; and this does not depend entirely on their being impregnated, for there were several whose oviducts were small, which were as large as the one which was found full of ova. Others were smaller than the males, and no way different from the large ones, except that the small ones were brighter in colour. Females of the common size were rather smaller than the males, and nearly of the same colour. The largest females were not so bright in colour; the yellow appearing dirty, but the brown equally as bright everywhere.

Of the Fat.—On opening the abdomen the fat appeared much whiter and more in quantity in the males than in the females. It is diffused among the intestines in small flakes slightly attached to one another, and lies principally on each side of the intestines. In the females the fat is very much in quantity in the autumn, but in the spring it is much less, and of a brown colour. The œsophagus is very small, about the size of a large horsehair, as it passes through the union of the thorax with the abdomen, and enlarges a little before it enters the stomach. The stomach is situated under the first and second scale of the abdomen, and is a transparent bag of the shape of an egg, about the size of a large pea, the large end towards the œsophagus. The œsophagus enters on the top of it. The small end terminates in the pylorus about the size of a hair-pin, which continues of this size for the twelfth of an inch, then suddenly contracts to a very small neck, which continues for the eighth of an inch, and then dilates to the size [of that] above; the intestine increasing gradually in size for about an inch, till it is of the thickness of a crow-quill, and, for one-fourth of an inch, continues of this size. It then diminishes a little for one-fourth of an inch, and here receives a vast number of small ducts, which probably answer the purpose of liver and pancreas. These ducts enter all round the intestine; the intestine afterwards gradually diminishes to the size of a hair-pin, and then opens into a large oval bag half as large again as the stomach. It is transparent, and has six small opake oblong bodies placed in the direction of the gut at equal distances, nearer to the upper part of the intestine than the lower. They are so closely attached to the gut as hardly to be separated from it; but I find they are only attached by the principal part of their surface; and at the lower end, or end next the anus, they are united to the gut. I suspect they are glands, and that at this end of union the duct enters. This bag is sometimes filled with a greenish fluid, and sometimes with a few fæces of an oblong shape, of a brown colour and shining appearance, like the ova of a grasshopper. The intestine contracts to the size above, and terminates in the anus, under the upper and last scale of the back, and superior to the first of the belly counting from below upwards. The upper part of the intestine above the liver is more transparent than the lower part, and appears to be convoluted, but it is only the circular muscular fibres appearing through the coats of the intestine; and the inner surface appears to be plain in the lower part of the intestine from the liver, but the muscular fibres run in a longitudinal direction. The intestine from the pylorus to the anus takes three spiral turns, and is about twice as long as the whole animal. What I conceive to be liver consists of a great number of small single ducts which seem to enter the gut separately. They are exceedingly small and numerous, about an inch in length, and folded up in all directions. On opening the abdomen and exposing the liver I have seen among these ducts a greenish fluid which looked like transuded bile.

The lungs consist of air-bags and vessels: there are two white bags as large as peas, placed on the upper part of the abdomen on each side, from the bottom of which goes a large air-vessel down each side, that receives the smaller vessels that have been distributed through every part of the lower part of the abdomen. The bags above receive the branches from the parts contiguous: the air-vessels are white and shining, and consist of a spiral thread in a circular form from end to end, which may easily be unravelled by pulling the vessel asunder, when the thread will wind off very easily. The air-bags and large vessels going down the sides are not of the above construction; they are white and opake, appearing as if covered with a fine white powder[1].

The nerves are like those in the silk-moth while it is in the caterpillar state. They go down the belly to the end, consisting of two small strings, and small round opake bodies placed at equal distances, upon the beginning of each scale of the abdomen. These white bodies or ganglions give off nerves on each side. In passing down the abdomen it goes over the division of the vagina [in the female], and a ganglion is placed upon the division which binds the vagina down close to the under part of the abdomen, giving off nerves to the termination of these parts.

The three eyes [ocelli] on the head project above the skull like half globes; they are shining black, and are fixed in the skull. When viewed in the microscope they appeared polished and black, but on removing the projecting part it appears transparent. They are hollow, and the lower part is sunk in the skull, at the bottom of which is a little fluid, and lined with a black part like the 'pigmentum nigrum' in the eyes of the more perfect animals, which gives them their black colour.

Male Parts of Generation.—The males may be easily distinguished externally by the above description. The penis, &c. is like that of the silk-moth. It is secured in a strong brown shining horny case, about the size and shape of a barley-corn, with two blunted hooks which bend downwards, with a sulcus in the upper part in which the penis lies. This case consists of two parts joined together above and below, with a tough union. At the end are the two hooks above mentioned, each of which open and shut, like forceps; probably to secure the female in the act of coition, like the hooks in the male silk-moth. These hooks project beyond the penis near the breadth of a pin. The case has muscles attached to it, by which the male can make it project and draw it in. The penis lies in the sulcus or groove and is about one-eighth of an inch in length, about the thickness of a common pin, is rather flat, of a light-brown colour, darker towards its end. At its end, it has two small projecting parts on each side, going off obliquely: they are thin, horny, and are smaller at their attachment, suddenly swell out, and are rounded off in an oval form. On the under side of the penis is a groove in which the duct for the conveyance of semen passes, which opens at the end between the two above-mentioned projecting parts. The penis seems not to be capable of being pushed out far; for I have never been able to draw it out more than the breadth of a hair-pin[2]. The testicles

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[1] [Hunt. Preps. Nos. 1073–1079.]

[2] [Hunt. Prep. No. 2349.]

are two small white bodies about the size and shape of hemp-seeds, sometimes larger and flattened: they lie in contact with each other, but may be easily separated: the right is rather higher than the left: they are placed under the second scale, and seemingly not attached to the back. The ducts or vasa deferentia come out from the testicle on the under side, nearer the upper than the under end, by very small ducts bending downwards, and pass down on the outside of the intestine, soon beginning to swell gradually to three times the thickness. At about half an inch from the testicle is a projection like a small bag or cæcum; the duct from above to this part appears rather opake and shining. Almost close to this bag another cæcum arises, on the other side and in an opposite direction, nearly three times as long as the other. This bag is generally more opake than any other part of the duct, and loses the shining pearly appearance; then diminishes quickly in size and makes a bend upwards, becoming very small; turns again downwards, and is about the size of a horsehair; is continued into the penis, where it unites with its corresponding duct at the beginning of the penis, and is continued to its end.

Female Organs of Generation[1].—The vagina begins or opens under the last scale of the belly, just before the root part of the sting; so the sting with its muscles, &c. are placed directly between the opening of the vagina and anus. The vagina runs along the inside of the abdomen for some way. As soon as the vagina enters the abdomen there is a bag attached to it, similar in situation to that in the female silk-moth, about one-fourth of an inch in length, and the thickness of a pin; round in the impregnated state, but in the unimpregnated it is flat, thin, and transparent, though of the same size. The length of the vagina, from the external opening to the division of the oviducts, is about one-eighth of an inch. It then divides into two ducts of the thickness of a hair-pin, which pass on singly for one-eighth of an inch; then each divides into six oviducts, which are slightly attached by small filaments of the air-vessels and ducts. The ducts appear knotty in some places, and gradually diminish till they are insensibly lost. They may be easily separated by dividing the small twigs of the air-vessels by which they are attached. The two divisions pass up distinctly for some way, through which division the largest part of the intestine passes. The ducts diminish in size, and terminate almost insensibly under the second scale of the back without any seeming attachment. The oviducts lengthen after impregnation in proportion as the ova advance in size; so that, in a female ready to lay, the oviducts are increased to near six times their

[1] [Hunt. Preps. Nos. 2632–2637.]

length in the unimpregnated state. The number of ova which is contained in one of the oviducts cannot be easily ascertained; but I have been able to count fifty, so that at this calculation she will lay 600 eggs. The eggs nearest the vagina are largest, of an oblong oval shape: the largest are about one-eighth of an inch in length, and they gradually diminish in size till they are insensibly lost. As the ova diminish in size they become rounder, till at last they become perfectly round.

Hornets copulate like the common fly, by the male getting on the back of the female, but in the act of coition he is bent almost round. The female is also bent, but not near so much; and during the act the male shakes his wings, and seems to emit like the male silk-moth[1], &c. The two which I saw continued between five and six minutes: this was in the beginning of October.

Of the Sting.—The sting is placed between the vagina and anus in the anterior perinæum, on a convex shell which is divided in the middle. It is about one-fourth of an inch in length, of a black shining colour. It is thickest at its origin, and flat, having a little groove on the end inside, which is lost in its middle, becoming flat, and the sting ends in a round sharp point. The sting is attached by a joint above the vagina, and is flat and broader at this part. The sting from this joint takes a bend which answers to the convexity of the shell. In the shell there is a groove in which the sting is received when not in use, so that when drawn back into this groove it does not project above one-half of its length. On the upper part of this shell are placed two small horny parts, about one-eighth of an inch in length, of the thickness of a bristle: they are convex on their outer side, flat on their inner, and when the sting is drawn in, it comes in between them and is of the same length exactly: they are darker coloured at their ends, and are there beset with small hairs: they are nearly of the same thickness through their whole length, are not perfectly straight, but take on a little bend laterally in the middle; they may be called 'feelers,' for they would seem to have a power of knowing what to sting by these two parts. The glands for secreting the poison are two small ducts about two inches in length, of the thickness of a horsehair, and nearly of the same thickness through their whole length, excepting within half an inch of the reservoir for the poison, when they become smaller, and enter that bag separately, on the upper part, about a pin's breadth asunder. These glands or ducts lie doubled up several times on each side above the vagina and beginning of the oviducts, and may be easily dissected or

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[1] ['Animal Economy,' p. 461.]

unravelled by dividing the small twigs of air-vessels which go to them.

The reservoir or bag for the poison is placed under the fourth and fifth scale of the back of the abdomen, and is about the size of a very small pea; it is of an oval figure and of a shining tendinous appearance. It is not a plain uniform bag, but the fibres of which it is composed take different directions, and there are small furrows in the direction of those fibres. It seems always turgid, and, when cut into, has but a small cavity in its centre. At the opposite end of this bag arises a duct for the conveying the poison to the sting, which is about one-eighth of an inch in length, of the thickness of a horsehair and very transparent, which is continued on the sting. The females only have stings[1].

Loose Notes.

The comb of the common bee is all of one colour, although the material brought in on the legs is of various tints of yellow, therefore some change is produced [in that material]. The same of the humble-bee. The combs of the hornet and wasp are of a darker and lighter colour, and that pretty regularly variegated. We should naturally suppose that the materials were of very different tints, they therefore probably undergo some change.

If the hornets' nest is taken away with only a little left, they begin anew. The males are the workers; they fly abroad for food, and feed upon ripe fruit, as grapes, in the beginning of October, while the females remain at home. They eat meat and ripe fruit, especially if it contains much sugar, as ripe figs: they are fond of sugar when wetted.

In the maggot-hornet, we see on each side ten dark spots, or tracheal openings [stigmata]. In the winged insect seven of the lower [openings] belong to the abdomen, and three to the trunk: the first [hindmost] of the trunk is behind the wings; one is between the [hind and fore] wings; and one is before the upper [or fore] wing.

I fed young hornets in the maggot state with bits of meat, by putting it in between their nippers when they opened them. The maggot-hornet, when full-grown, spins its web over the mouth of the cell, but not on the inside. When they have spun themselves in, then they change their maggot coat.

Mr. Grant saw only one hornet at Gibraltar.

"Beckenham, Dec. 4, 1784.

"Dear Sir,—People never give attention to matters which are continually before their eyes; and, therefore, I do not find it easy to collect

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[1] [Hunt. Prep. No. 2156.]

from any of my labourers or woodmen a single idea respecting the hornets; and some of them are acute intelligent fellows. They say that in splitting old trees in the winter they often find deserted nests; and I saw the remains of one which they had broken last week in splitting an oak. They are confident that these nests are always mere combs, and without grubs. They also say that they often find in old trees, a solitary and dead hornet, but never more than one at a time in the winter. When you ask them about the regeneration for the ensuing year, they stare, and know no more than my Lord Mayor. I have often seen Mr. King's nest, and will revisit it as soon as this heavy weather ceases. My hornets disappeared gradually, and were all gone in the first week in November. I think it probable that there will be a new nest in the same place next year, and yet I firmly believe that all of this year are gone to the devil, and are as dead as Julius Cæsar. We send three dozen swans' egg-pears, &c., with our compliments to Mrs. Hunter and you.

"Yours ever truly,

"WILLIAM EDEN[1]."

Economy of Wasps.

Of the Progress of Breeding.—At any time of the summer, excepting at the beginning and termination of their colony, we find all the different stages of propagation, from the half-formed cell to the egg, the maggot, the chrysalis, and the fly. At the very first we only find eggs, and those of different ages, then those are hatched into maggots in succession; while the maggots are increasing in size other eggs are hatching, and fresh eggs are laying. The first laid are then becoming chrysalises, while at the same time the wasp or wasps are increasing the hive; so that we have in a nest, at this stage, eggs of all ages, maggots of all sizes, and chrysalises; all on each platform. As a platform is beginning to be formed at its centre, by probably forming at first one or more cells, we find as soon as one cell is finished an egg is laid in it, and as the comb extends in circumference so are the eggs laid; so that we have the whole progress of generation in the same platform beginning at the centre and extending towards the circumference. Some time afterwards, in the centre of the platform, the first eggs hatch, becoming maggots, then chrysalises, then flies, and they are gone; leaving empty cells half-broken down and probably a second set of eggs in

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[1] [William Eden, Esq., son of Sir Robert Eden, Bart., of West Auckland, was raised to the Peerage of Ireland, by the title of *Baron Auckland*, 18th November, 1789, and was created a Peer of England, under the same title, 23rd May, 1793.]

them. Then the order becomes inverted, and we find the youngest towards the centre, and the oldest towards the circumference, while there are new-formed empty cells on the outer edge of all. But this order at last becomes irregular; and they go on in irregular succession: the centre cells at first held eggs, while the circumference was only forming; the cells, here, have eggs when the centre cells have maggots; and then the circumference-cells have maggots when the centre ones have chrysalises, and by the time that the circumference-cells have chrysalises, the centre cells have a second set of eggs; for every platform produces several successions of broods. At the latter periods in the season, when the lower platforms are making, we have the same succession going on in them, but they are larger cells, having the eggs, maggots, and chrysalises of the males and young queens in them; and sometimes we shall have in the last platform small cells, and either queen-eggs, maggots or chrysalises in them. By this time the upper tiers are forsaken, although they may be still forming lower tiers of large cells; and, towards the latter part of the season, we have only the lower cells, filled with queens and males; and in the month of October only queen chrysalises in the lowest of all.

Of laying the Eggs and Breeding.—I have already observed, in the description of the formation of the comb or platform, that, as soon as she [the mother-wasp] had begun her first platform, consisting of only three or four cells, she immediately lays in each an egg, even before they are completely deep, which eggs are hatching while this platform is enlarging in the number of cells; and she continues to employ the cells as they are forming. The grubs, when hatched, she must feed; and, probably, the cell not being complete, fits it better for her to perform this duty; for it appears impossible for her to get to the bottom of one of the small cells when complete.

At this time she has a great deal of employment till the offspring are capable of providing for themselves and of assisting her; then they probably leave her entirely to the office of laying eggs; and they are employed in future in carrying on the increase of the building. Immediately upon the formation of a few cells in the second partition the female lays eggs, so that the laying of eggs goes on progressively with the formation of the cells. On removing a part of the external case and looking in laterally between the platforms and observing their actions, we may see that they most commonly pass along the under surface of the platform with their backs downward, by which means they can more readily pay attention to their young. At the time the young queens are beginning to be formed, the nest consists only of queens and labourers, and it is now at the fullest respecting labourers;

but these decay, being either killed or dying abroad; and about the month of October the males and queens are in the greatest number in the hives.

Of the Egg.—The time the egg takes to hatch is not known, nor is it easy to be known; at least, I have not been able to inspect the parts at stated times: but, by taking the whole progress, I am led to suppose it cannot be long; probably only a few days; for, in a wasp's nest in which I observed its progress from day to day, I could make a guess. When the egg is hatched the maggot becomes the object, first of the queen, and then of the young brood themselves; they are constantly employed in feeding the young, and for that purpose the maggots have all their heads towards the mouth of the cell, and of course downward[1]. It may be difficult to find out all the modes of feeding the young. We must suppose at present that the queen or mother of the whole feeds the first brood of labourers; but, when once two or three are arrived at the wasp state, then they immediately release her of that office, as well as of the office of building. As the labourers serve the queen in building and feeding, a question naturally arises,—Do the males and the young queens take upon them the office of feeding? I think it is probable the males do, as they go about for their own food, and come forth early enough in the season to feed the maggot-queens; and from an experiment, they seemed to feed the maggots. The maggots are fed probably with the same kind of food which the old ones eat themselves. I have caught the labourers coming into the hives with the materials in their mouths or forceps. In some it has been a small fly; in others the pulp of fruit; in some, pieces of meat; and, in squeezing by accident some of the maggots, I have squeezed out the juice of the cherry. They have two teeth, or rather pincers, which open laterally, and which they are often opening and shutting. As their tails are towards the bottom of the cell their excrement must be deposited there, which is allowed to dry: it is of a black colour lying at the bottom of the cell; so that the old ones never clean them. The maggots can live a long time without eating: I have known them three weeks before they died. This power of abstinence must often be put to the trial, as often as the weather is such as will not allow the old ones to go abroad.

The maggots cast their external coat; but how often I do not know. I have found them, when about half-grown, with their coat half off, as

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[1] [Nothing is said of the attachment of the eggs to the sides of the cells when they are deposited in them, which I believe is always the case, by a pedicle.—W. CLIFT.]

if creeping out of it, and the part which had freed itself of the tail was at the bottom of the cell adhering to the excrements. They have no progressive motion even when taken out of the cell, and their motion in the cell is but little. I observed, when the comb or partition was perfectly free from motion, that the maggots were motionless; but by touching any one part of it the whole of the maggots would instantly move; so that the whole surface was in motion, and then immediately became quiet again. This was probably in expectation of food, like young birds. Whether they see or not, I have not been able to determine; but I can observe two dark lines on the sides of the head, placed on two globes which are hard to the touch.

If by accident the chrysalises are misplaced, the old ones replace them. I observed wasps take some maggots that had tumbled out in their forceps, and carry them from place to place and put them in an empty cell. When the maggot-wasp is ready for the chrysalis state, it makes its own covering for the cells, and also lines it at the bottom; but the lining becomes thinner and thinner towards the bottom. I observed them at work weaving the white lining, before mentioned, from a small thread which came out of their mouth, by which weaving the maggot becomes much smaller in size. It then seems to rest from its labours of eating, and begins to change the present parts for those peculiar to the fly-state, which now begin to form. Their maggot-coat seems to get loose, and the parts within may be seen through it. What was the head of the maggot seems to decay, and the two eyes of the fly are seen on the shoulder part of the maggot; the head of the fly having formed on the shoulders of the maggot.

It would appear, then, from the above observations:—*first*, that the egg is laid in a cell; *secondly*, that it is not necessary the cell should then be complete, perhaps better that it be not; *thirdly*, that most probably the cell is completed as the maggot grows; *fourthly*, that the old wasp feeds the first young in the maggot-state, and the succeeding ones are fed by the labourers; *fifthly*, that the maggot, when ready to fall into the chrysalis state, covers itself with a juice spun out of its own body like the silk-worm. While in the cell, a complete change is made; there is not a single part of the old body remains, and the new parts formed are much more numerous than the old; of which transformation, although probably the most curious part of the whole, yet as I do not conceive there is any material difference between it and that of insects in common, I shall not take notice here.

Of the internal parts of the Maggot.—The œsophagus is very short and small, and swells into an oblong bag, the stomach. The stomach is very near the whole length of the animal: it passes in the direction of the body, surrounded by the air-vessels and the silk-vessels. Towards the anus it becomes smaller, forming what may be called gut, and which is afterwards elongated into a gut, lying coiled up on each side of the stomach; under the above described air-vessels, there are also four long canals, two on each side: their beginning is forward, near the beginning of the stomach: they pass backward and toward the beginning of the intestines, becoming rather larger; they then unite into one on each side, and at last enter into the gut, or termination of the stomach. This is what I suppose to be the liver; probably they may secrete a liquor (juice) similar to that of the pancreas[1]. These appear to become longer and smaller in the adult or wasp-state. In the interstices of these parts is a kind of cellular membrane, having also a vast number of white bodies in it, which appears to be analogous to the fat in the old; for we find in young animals in general that the substance in the place of the fat in the old is hardly fat: the same in the belly of the chrysalis. They have a number of lateral air-openings, which all unite into one canal that passes from head to tail; from which passes inwards toward the stomach, a vast number of air-cells, as also laterally into the different parts. These are now mere ramifying vessels, probably from air being only wanted for respiration and not for flight; therefore they are not enlarged into cells.

Of the Silk Glands.—On each side of the body intermixed with the above substance, are canals for the purpose of secreting the juice for the covering of the cells, somewhat similar to the silk-worm. They begin by two canals on each side near the tail, and pass, very much convoluted, towards the head. These unite into one duct which opens at the mouth, through which the juice passes to form the silk. These canals make up the largest part of the substance between the skin and the stomach, and which makes the animal shrink so much after it has spun the lining of its cell. These substances immediately under the skin are divided into two portions, one on each side; which division we see through the skin on the back, being divided by the heart: and we also see it divided on the fore-part by a dark line, so that the cellular membrane on each side do not commonly unite with each other.

I began my account of the wasp in the summer with one female wasp, and have traced her operations till she produced assistants, and I have still continued the work till the whole was completed; but I have yet only spoke of her breeding at large. It is now necessary I should take notice of her offspring, because there is a peculiarity in

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[1] [Urea has been discovered in it.]

their production that I believe belongs to no other kind of animals, and only a few of this kind.

All animals of distinct sexes, so far as I know, produce distinct sexes; but for a male and a female of any species to produce naturally one of themselves in every respect but in sex, is I believe peculiar to some of the species of this tribe of insects.

From these observations we must suppose there are two kinds of wasps bred in every hive; one kind are the 'male' and 'female,' which complete the species; the other kind is that which does not breed, although having the female parts, and it constitutes the 'workers.' These are not bred promiscuously with the others, as the male and female are, but they have their two stated times. As the first parent requires assistance, the first wasps she breeds are the 'workers'; and her instinctive principle goes hand in hand with the necessity for her first, second, third, fourth, fifth and sixth platforms of combs, all of which have only small cells fit for the hatching of 'workers'; so that a hive consists at first only of the queen and workers. The latter are increasing fast; and we may observe them to be the only useful part of the community; for neither the males nor young females are probably of much use. About the middle of August or September they are increasing their seventh, eighth and ninth platforms, the cells of which, especially of the seventh, are some large, some small, but those of the eighth and ninth are mostly large. In the small cells, I believe, the queen lays the eggs that are to be males; but late in the season, and in the large cells, she lays the eggs that are to form the fertile females; so that the male and the female are the last that are bred; the reason of which we shall see by and by.

Of the Workers.—The workers constitute the largest number in the hive. They are, upon the whole, the smallest in size, and they have more variety in size among themselves than either the male or female have. They have the female parts of generation, which are extremely faint, but easily distinguished; I never found them impregnated, and, as I have already observed, they have the sting, which also is another part peculiar to the female*. Their belly terminates in a very sharp point, coming to it quickly. Their feelers or horns are shorter than the male; six scales on each side; of which the upper overtop the under entirely, and the anterior overtop the one behind. The workers are what are found abroad, especially towards the beginning of the summer. By size alone, they are immediately to be distinguished from the breeding females, but not otherwise; from the males, to which they come nearest

* The parts of generation of the working wasp are much more evident in some individuals than in others. (Loose note.)

in size, they are to be distinguished both by the shape of the abdomen and by length of their feelers, besides their having a sting. The abdomen in the worker is shorter and more pyramidal than in the males, being thicker at its base, and coming almost to a point, having the two last scales terminating in a point. Their feelers are not so long as in the males. They are called 'workers' because properly they do all the work of the family; for as soon as one or two are formed, they are immediately employed, and as they increase in number the greater proportion of the hive is built. Their employments may be reckoned three:—first, the excavation of the ground, when the hive is formed under ground; secondly, the building of the hive; and thirdly, the providing for and feeding the maggots.

When a hive is examined any time before the months of May, June, or July, we shall find nothing but a queen, which is very large, being full of eggs, and workers; but this time [or state of things] will differ in different hives. About this time they are strongest in labourers, for their season of breeding is now over, and as they are considered a common enemy they are all destroyed, when possible, besides the common chance of unfavourable weather, &c.: so that by the latter end of September or beginning of October they are becoming few in number; for in a hive that I took on the 8th of October, I only found fifty-eight workers, and a little later they are probably dying a natural death.

Of the Female.—The fertile females or queens are considerably the largest, above three times the size of the others; but so similar in shape as to appear like a worker magnified. The anus terminates in a sharp point, like that of the workers, and they have a sting. Their feelers or horns are similar to those of the workers. From this description, they must appear to be similar to the workers, only much larger. I believe the old queen never goes abroad after having produced the workers. In the month of August or September, I have observed that the young queens are bred in the lower and last three or four tiers of platforms; and, of course, they are the latest in the season. They are much larger than the males, and in shape, &c. are exactly similar to the workers, excepting being much larger: they are like a worker magnified.

They do not come out of the hive to get food for themselves, but have their food brought home to them by the workers, and probably by the males; for the males feed themselves abroad; but whether they bring anything home I do not know. I never could see the females going out, like the others, nor do we ever find them feeding on fruit, meat, &c.

As they are bred in autumn, and are never seen in the winter, they can only be examined at the former season; and they are then extremely fat; the abdomen being filled with small granulated fat. When the parts of generation of young queens are examined, we find the oviduct,

&c., but in what may be called a maiden-state; consisting of ducts only, without contents. About the beginning of October they copulate, and then leave the hive and go to their hiding-places; leaving behind some labourers and males to die: but this will be sooner or later according to the weather, which affords them provision.

Of the Female Parts.—They consist of a vagina which lies under or behind the first scale of the belly, just before the root of the sting; so that this opening is between the sting and the last scale: it passes a little way into the cavity of the belly, and divides into two ducts. Each of these two ducts receive at once six ducts in which the eggs lie, making what may be called the 'ovaria' of the right and left sides; which are separated from each other by the stomach or gut passing back between them. These two portions come into contact behind the stomach, are united by the air-vessels, making but one bundle, which becomes smaller and smaller towards their beginnings, where they seem to begin insensibly small. The length of these ducts is very considerable; for they pass up slightly convoluted, and would seem to arise as high as the thorax; when in an impregnated state the convolutions are very considerable. When we examine the queen, when she is in the height of breeding, we find these twelve ducts very much thickened, being now filled with eggs of all sizes; and when in such a state they are much longer; too long for the length of the abdomen, and are therefore thrown into folds. They first pass up convoluted as high as the thorax, and are again bent down upon themselves, passing along the back, near to the termination of the abdomen, and up again to their origin, which is as high as at the heart, where the canal passes out of the thorax. As they pass from their origin, in the impregnated state, they are becoming larger and larger, and of course the ova which they contain are also larger, the lowermost being such as are just ready to be laid.

Of the Male.—The males are next in size; they are rather larger than the largest workers. They are longer in their belly, which is more of an equal size through its whole length, terminating at the anus more in a blunt end; the last scale of the back of the abdomen terminates in a broad edge, which projects much further than its corresponding scale underneath. Their feelers or horns are much longer than those of the workers or queens. The males I believe are the next formed [after the workers]; they are begun to be bred in August. In a hive that I examined which had about six tiers of cells, there were a great many eggs, maggots, and chrysalises in the cells. I deprived them of their queen, and the labourers repaired the hive, continued to feed the maggots that were hatched and those that were hatching, and, when

I examiued the hive in September, there were but few labourers, and a great many males, but no young queens. The males have no stings. The males go abroad and feed themselves; for we find them on fruit, &c., yet I could conceive that they also receive food at home; for in one hive that I brought home in September, where there were few labourers, the labourers were lively and restless; but I saw no males for several days, when they became very hungry, and then they [the males] came out of the hive; but whether they carry home anything to feed the maggots of the young queens, I do not know. But from an experiment I made to see if they fed the young queens, I suspect so; for the males and young queens were often seen having their tongues or mouths together, and raising themselves up against each other, keeping themselves together with their fore-feet; but I could not say that the males were actually feeding the females. The females often appear to be feeding themselves.

Of the Male Parts.—They appear to have but one testicle, which lies on the back near the middle of the abdomen; at least if there are two, which most probably there are, they are united so as to seem but one, like the udders of animals: it is large, and of a quadrangular form. From the lower surface, and at some distance from each other, pass two small ducts towards the anus, which, when got a little way, dilate into two long bags, or open into two large oblong bags. These bags pass on in the same direction, and either enter into or are joined by two canals or long ducts which are curved, lying on the top of the others. The common duct of these two joins the corresponding duct of the two of the other side, forming what may be called 'urethra.' The gut passes over the testicle, and then between the two small ducts, and gets behind the other side to reach the anus. The penis is a horny substance, as is I believe the case with most insects, both for the purpose of conveying semen, and for holding the two parts together. The passage for the semen passes in the centre of this body, and projects a little way between the two holders.

Of what becomes of Wasps after having finished their Propagation.—A wasp is of that class respecting propagation in which the females live through the winter, but the males die; for I have shown that the queen begins the colony in the summer, therefore she must have lived all the winter. The better to enable her to do this, she is at this time extremely fat, which fat is of a very pure white. I have shown that the workers are first bred, with a view to be ready to assist in bringing up the future workers, the males, and the females or young queens; and when that is completed, I have reason to suppose they are dying away; for in the instance of a wasp's hive which had been very strong in the summer, when I took it on the 8th of October, there were only fifty-eight labourers in it, and at this period they are very lean, therefore unfit for living through the winter.

About this period I suppose the males and young females copulate, and when this is over, that the males all die; and what makes this still more probable is that they are at this season very lean, similar to the labourers. I also conceive that the old queen dies in the autumn, but at what time I do not know. The young queens about this time become very indolent, and would appear to be weak, although it cannot be supposed they are so, being now extremely fat. Their oviducts are pretty large, and have small ova in them, which is not the case with the workers.

Of their Winter Retreat.—By the latter end of October the hive is deserted, by the workers first, then by the males, and lastly by the young queens. The two first I suppose die; but what becomes of the queens I believe has not been commonly known: they hide themselves in winter in holes in dry banks.

Many things are discovered when in pursuit of something else, more especially if it is a subject we may at the time be engaged in. It was one of the orders I had given to my gardener, that, when he was digging in the winter, he would be attentive to what he dug, and see if he ever dug up a wasp, hornet, or humble-bee. In digging a dry bank about the beginning of April, he dug up three wasps alive; they were in holes like worm-holes, not a great way from the surface. They were coiled up like a wood-louse. He brought one into the hot-house, and it became lively.

Mr. Fergusson told me that Lord Auckland's[1] gardener told him that he turned up a live wasp among some leaves of trees in the month of December. They sometimes come abroad in fine weather in the winter: my gardener saw a wasp of the large kind in March, but could not catch it. The weather being fine, one was caught in the month of April, which was a female, which had eggs in the ovaria, but not farther advanced than those in the month of October. To see if I could keep wasps through the winter, I closed up the hole or door of a wasp's nest about the beginning of November to confine them in; but they set to, and made a passage out. However, I was at last able to confine them; but by the end of November they were all dead, and I found they had filled the space between the nest and ground or vault with surrounding earth, all loosely mouldered down, which probably was the earth they had removed to work their way out.

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[1] [According to the date of this MS., 1789, Hunter's friend and correspondent had obtained his title: see note [1], p. 82.]

In October, 1788, I took some workers, some males and some females, and enclosed some of each in the following places: in a box under ground, so deep as not to be affected by the frost; in a thick wooden water pipe, which was closed at each end and left above ground; and in a hole in the middle of a brick wall, the wall being built up again. About the beginning of May, 1789, those places were opened, but the wasps were all dead; from which I should suspect that very few survive the winter.

Loose Notes.

Wasps bear being removed from their first place of destination, taking kindly to a new place of abode, and pursue their labours. I have moved a hive out of the ground to a considerable distance, placed it under a glass shade, and they have continued their works just the same as before. Hence we must imagine they are a manageable set of creatures, and, I think, much more so than bees; but they differ very much from bees in the advantage to man arising from cultivating them. They are extremely destructive in their labours, and no advantage arises from those labours; while the bee is perfectly inoffensive in its labours, and is advantageous in their result. If deprived of their queen, the labourers still go on with the work; if the hive should be very much injured they will repair it, and they will even increase it in size. Whatever eggs may be laid, they are hatched, and the maggots are fed, and go through all their stages.

As the wasp commonly builds her hive under ground, and as she is obliged to excavate the place lower and lower, the cavity is at first commonly of a rounded figure, but it becomes more and more oblong as it descends. However, the rounded end is still rounded off, which makes the last tier or platform narrower than those above; and these they would widen in the end, if the season for leaving off did not prevent them. But where they are not obliged to mine, and where the hollow is of equal size, they make each platform of the width of the cavity. This I saw in a bee-hive, as also in the hollow of a tree, where wasps had built.

The best mode of killing the inmates of a wasp's nest, is to dig a hole by the side of it lower than itself. If you come upon the nest, have a piece of glass and clap on the hole; then go on, and when below it, make an opening up to the nest. When this is done, make a kind of vault from this hole sufficient to put a match in, made of wetted gunpowder, and set fire to it, and by stopping the opening of this vault, the whole of the smoke will ascend round the nest. Immediately stop up every crevice to confine the air as much as possible.

There is a small long wasp, which is not a small common one; for in one of these, in the beginning of June, I found eggs fit for laying; therefore she must have been a queen.

Lord Gage informed me of a gentleman who, eating an apricot, was stung in the tongue by a wasp. That a gentleman present immediately applied a piece of onion to it, then another; and after three or four applications the part did not swell, nor was it painful [1].

Economy of Beetles.

Of the Beetle-tribe [*Coleoptera*].—The beetle differs from other flying insects in several particulars. A beetle is very strong in the legs; it is difficult to confine them in the hand, and I imagine the intention of this is, because they burrow. I imagine also that, because they burrow, they have two moveable scales like wings [elytra], which cover the true wings, and guard them in the act of burrowing.

The abdominal viscera adhere only to the under scales, not to the upper; which renders the viscera loose after the under scales are removed, being only then attached to the thorax, at its upper parts; however, there is a thin membrane which covers the upper surface of the viscera, to which the viscera are attached.

Beetles I imagine do not feed upon the wing; and, as they do not, their powers of flight are not equal to many of the flying insect tribe.

A maggot-beetle I believe does not spin a web over itself when it goes into the chrysalis state.

Of the May-Chafer, or Black-Beetle [*Geotrupes stercorarius*].—In the month of June the young ones are found in their maggot-state, in their nests, pretty far advanced, going almost to change into the chrysalis. These nests are in the ground, and generally grass-ground where there is cow-dung, and mostly under the place where the dung lies. They are about twelve or eighteen inches deep. There is but one young one in each cell: its maggot-coat is becoming very loose about it, and about the latter end of the same month they would appear not to be much further advanced. In the month of July they throw off their maggot-coat, and become chrysalis. Whether they change their coat in the maggot-state I know not.

Their nests are in clusters, three, four, five, six, or more, close together. Most probably these belong to one or two female beetles, as

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[1] [Cake indigo, wetted and rubbed on the part stung, has the same effect. This application is universally resorted to in Epping Forest, where wasps are plentiful. —Wm. Clift.]

we generally find about four eggs in the female. They have two teeth [mandibles], one on each side. The excrements which belong to the maggot only, are soft, of a brown colour, and pretty uniform; which last shows a considerable degree of digestive powers. The chrysalis does not become so dry as that of the fly, moth, &c., by which means their extremities are not bound down by the drying of the chrysalis skin. This difference may arise from the chrysalis of the beetle being in a moist place, such as underground; while those of the moth and fly kind are suspended in dry places. The maggot-beetle has no occasion to enclose itself before it forms the chrysalis, as that of the butterfly does.

There are nine nervous centres, one of which is near the head, having a vast number of white radii passing out from them, which ramify on all parts of the animal. The stomach passes down almost through the whole animal as in the silk-worm: it is large, making near the whole bulk of the animal; near to the extremity of the animal it contracts and forms a gut; but it immediately dilates into a very large bag which has a fissure in it, making it appear externally like two bags or bodies: these appear as if quilted on an external view, which arises from the structure of the inside. The bag again contracts, and opens externally, forming the anus. Lying close to the outer surface of the stomach are the same vessels which are found in the silk-worm, like threads, and coiled up irregularly; which enter the canal a little above the bags before mentioned. Some of these are yellow, others white.

This beetle is fully formed at the latter end of July, and all the month of August, and often in September; and in general they fly about in the evenings, and with considerable force. They are found very commonly upon cow-dung, under which they often bury themselves all night, but not deep. In the month of August and September they are found in the evening crawling and flying about cow-dung, which they would appear to live upon, and are found digging holes in the ground either under the cow-dung, or near by it. Those holes are about twelve, fifteen, and sometimes eighteen inches deep; and when below the surface some way they often divide into two, three or more holes: into these holes they carry a small quantity of dung, which just covers the bottom of the hole upon which they lay an egg; they then fill up the hole above the egg with more dung, for about two inches. The dung is not allowed to touch the egg, for it is formed into a small cup round it. In the month of November I found that the eggs had hatched, and pretty large maggots were formed, about one-third of the full size; and the cup in which the egg had lain was now become larger from the feeding of the animal.

About the latter end of August, September, and often in October, according to the fineness of the weather, they begin to disappear, and are found buried in the ground about six, seven, or eight inches below the surface in perpendicular holes made by themselves. These holes are often made in loose ground. When they first take up these habitations, the passage leading down to the animal is not filled up; but the earth which they dig and bring up in making the hole, lies about just at the mouth of the hole, and is extremely light, so that the least blast of wind blows it into the hole, by which means they are covered over.

They also bury themselves in the holes where they have laid their eggs, just above the nidus or dung. They bury in societies, so that we find ten, fifteen, or twenty or more holes, all close upon one another. Whether these little societies are one family or not, is not easily determined. In these holes they lie the whole winter; and I suspect that most of them die before the spring comes in; however, not all, for I have seen some of them in April and May, which is much too soon for the hatching of the eggs; but their numbers at this season of the year are very few, and most probably they die soon.

Upon digging away some earth close upon these holes, I was able to split these holes in their direction downward, where I found the beetle always placed at the bottom with its head upward. They were very lifeless, but upon placing them in the sun they became very brisk. At this season of the year it very often happens that the ground is tilled where vast numbers have buried themselves. When this is the case, and if it happens to be good weather, they are seen flying about in great numbers.

Of the Cockchafer [*Melolontha vulgaris*].—This beetle flies about in the beginning of the months of June and July; commonly about the tops of trees, houses, &c., to copulate. They became very few about the 20th of July, 1788, and in a few days were entirely gone. However, I found one alive on the 26th of August in which was food in the bowels; and the ovaria were pretty empty.

So far as the shell-wings [elytra] cover the back, so far are the scales on the back soft; but, towards the tail, the two last scales are hard, not being covered by the shell-wings.

The feelers terminate in three branches, which are flat, and which close one on another, so as to look like an oblong body on the end of a stick. Those of the males are larger than those of the female; and when in copulation they spread them; but the female does not.

The males are smaller than the females. The same with the lady-birds of Barbadoes, both white and dark, which appear to be a species of cockchafer. They are of the same size with ours. The males have more hairs on their posterior thoracic scales. The thoracic scale in the female is mottled or tortoise-shell. The penis is horny and terminates in two hooks, which I imagine lays hold of some part of the vagina. Towards the last of the season I found a vast number of males whose penises were separated and the root projecting.

The female parts are two ovi-clusters; each consisting of six ducts, having in each only about six eggs which are oblong; each of these six terminating in one duct, making two ducts for the two clusters, which again terminate in one. This common duct to the whole communicates with the receptaculum seminis; or they both open externally by one common opening; so that there is no duct passing from the one into the other, as in the moth, &c.

The receptaculum is pretty large. There are not the glands for the sticking mucus, as I suppose that is not wanted, the eggs being laid in moist places, &c.; but [in the female] there is the second or single bag, filled with a white mucus, whose duct enters the common duct of all the ovarian tubes, as in the moth. This part must have a fixed use, as it is found in all[1]. The opening of the anus is distinct, nearer to the back of the animal. They copulate somewhat similar to the quadruped, or perhaps rather like a bird; the male gets on the back of the female. They are about fifteen minutes in the act; sometimes more, and sometimes less.

On the Rose-beetle [*Cetonia aurata*].—This is a flat green beetle with some small irregular specks of yellow, found commonly on the flower of the *Spirea*, also sometimes in the male parts of the rose, and which I believe feeds on the pollen. It is seen in the months of June, July, and till the middle of August; it is seldom seen to fly, but it flies if much disturbed. When confined on the ground under a shade, it buries itself and comes up again. The male is I believe the larger of the sexes. The female is of a brighter green, having few or no yellow specks.

Of the Grasshopper [*Phasgoneura viridissima*].

A large green grasshopper with small eyes and a long projecting tail, was caught in the latter end of August 1789; it was a female. Her belly was full of eggs, which were black, and pretty long; but when they were small they were of a lighter colour. She had a long oviduct like an intestine that passed between the two ovaria. Just before the termination of the oviduct, or near its opening externally, was a round bag full of mucus [spermatheca], whose duct entered the oviduct.

[1] [It is to receive the fertilizing fluid from the male, and apply it to the eggs as they pass outwards.]

The air-canals were of a reddish colour, just as if containing some red blood. They seemed to contain no more air than what might serve for respiration.

It had two very strong forceps [mandibles] making the upper part of the mouth, the tongue lying on the under side or behind, and a thin flap on the fore-part. There are other two, smaller and a little longer [maxillæ], just under them, which would appear to be conductors of the food. There are, also, short tentacula [palpi]. The tongue is a broad flat body, and seems so attached to the under part of the mouth, as that both move together.

The œsophagus begins on the posterior part of the tongue as in other animals, passes through the neck, and in the thorax it becomes wider and wider. It then contracts and immediately terminates in a little pyramidal body, which is lined with a horny substance, which forms longitudinal ridges, and which are serrated, fit to divide the food before it passes into the stomach. The stomach at the upper end forms two kind of cæca, and the above pyramidal body lies between them. One of these cæca is forwards, the other posterior, answering to the form of the body, which is deeper between back and belly, than from side to side. This stomach is just at the termination of the thorax into the belly.

The large green grasshopper feeds upon animal food, for it eats boiled meat. It tears it off with his two pincers, and the four short tentacula guide it. They will hold a piece of meat between their fore legs and chest and bite at it. I put a caterpillar to this grasshopper and he devoured it soon.

A grasshopper has two claws on the extremity of each foot; also two on what may be called the heel of the hind foot only. Along the sole of the foot of the hind leg are two rows of eminences, four in each row; the two next to the external claws are the largest; those at the heel the next in size. The eminences on the fore and middle feet are somewhat different. Their legs are in pairs, and each leg of each pair moves alternately. The two pairs of fore legs generally move twice for the hind legs once, by which means the hind legs move a great deal at once. He moves two legs at a time; if he moves a right fore leg first, he also moves a left middle leg: then the left fore leg and with it the right middle leg; so that in the motion of the four fore legs or the two pairs, there is only the progress of one pair. This is exactly the same with the trot of the quadruped, only it has not the jerk.

The feelers [antennæ] are moving constantly and in all directions; they are sufficiently long to touch bodies behind the grasshopper.

When walking upon glass standing on edge, they very often nibble at the soles of their feet with their mouth, which I suspect is wetting the eminences with something a little sticky, for it is those eminences that they seem to be at work upon. This grasshopper drinks freely, and ate a chrysalis of some butterfly.

There is an iris to each eye. Each eye is a hexagonal tube. The eye of the large green grasshopper has the appearance of a dark spot in that part directly opposite to the point of sight of the spectator, and therefore appears to move as that point of sight moves; but this probably is a deception, for most probably it is owing to the cornea permitting only the rays to pass in the direction of the axis of each of the ocelli, which, being dark at the bottom, the rays are not refracted at that part; but the tunica sclerotica of each eye, being green, and the sides of it reflecting the green rays, the whole eye appears green, excepting the above-mentioned dark spot. This fact of the sides of each eye being green and reflecting the green rays, shows that the object must be made at the bottom of the eye, not at all at the sides; and the green colour being reflected in every direction from the eye, excepting the spot, preserves the universal green colour that is necessary for the animal.

Their eyes would appear not to be fitted to near objects; for they seem to trust more to their long feelers, moving them in all directions; and when they touch anything with them they make a spring; and this takes place in the light, and yet they do see. When they make a noise, which is with their wings, their abdomen contracts and expands much faster than common.

Of the Dragon-fly [*Æsthna grandis*].

August 18th, 1778, at eight o'clock in the evening, I saw the dragon-fly flying about, making short turns, which were performed very quick. I also observed gnats flying; and, what took my attention most, was his making up to a gnat, and then the gnat was seen no more; therefore I conjectured he was feeding upon them. I caught him and opened him the next morning, and could observe in the stomach the scales of some insects.

The stomach is a straight canal, the termination of which is surrounded with what I suppose to be the pancreas. The gut goes on pretty straight to the anus, and opens just below the tail. Near the anus is the entrance of the ducts which I suppose to be the liver[1].

The ovaria of the dragon-fly is a distinct kind from any of the others; they consist of two, one on each side of the gut, reaching as high as the thorax. They are large at the upper end, becoming smaller downwards to the anus; each consists of a long bag; and on the inner side

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[1] [Now regarded as urinary tubes. Prep. Nos. 598 & 784.]

there are a vast number of small canals opening into it, something like the grains of corn going from the stalk. Each of these canals contains one egg or more. The large and long bags hold the eggs as they come from the smaller canals till the time of laying.

Near the anus these two unite into one, or open into one which may be called vagina, which is a common duct to them, and the reservoir of the male semen. The reservoir for the male semen is a round bag whose duct opens externally, and is the passage for the penis. There are two small glands, one on each side of this bag.

A dragon-fly has the largest eyes of any insect: it has a vast number of black spots which move with our eye, as they do in the grasshopper, but there is one principal one in the centre of the others. They copulate in October.

The attitude of the dragon-fly in this act is very singular. The penis is about the middle of the body of the male, and the vagina of the female at the extremity of the abdomen; and, during the act, the male embraces the head of the female with the forceps at the end of the tail. The female is in a circular position, the male, therefore, has his head and wings at liberty and manages the flight.

Of the Tenthredo Abietis. Linn. Syst. Nat. 193. [*Aphis Pini, or Aphis Abietis.* The description does not apply to any of the *Tenthredinidæ.*]

This fly has four wings like the bee; two very large and two much smaller. The wings are very large for the size of the body, do not lay flat or horizontal over the upper part of the abdomen, but their inner edges are raised, and they fall off slantingly on the side: however, this position varies. The colour of the body is of a light brown, but the wings are green, being the colour of the tree they frequent. They are of two sizes, at least in the abdomen, which is longest in the female; at least the smaller one does not lay eggs, therefore I suppose it to be the male.

They are different from the common insect in having but two states: the first being neither maggot nor chrysalis, but rather appearing to be an insect of the second class, viz. spider, bug, &c. [*Aptera*] and afterwards getting wings.

Although possessed of long wings, yet I suspect their flight is but very short; for in a spruce fir I found them breeding for several years, although this tree was only a few feet from others of the same kind, where none were ever found.

I suspect their life is but short, something like the silk-moth: that the male dies when he has completed the copulation; that the female lays her eggs, and dies; and that probably neither sex eat when in the fly-state. I suspect they lay their eggs in the bud of the fir, which remain through the winter and hatch in the spring, when the bud is going to shoot forth. The little animals feed on the inside of the cell, which increases the cavity; and as those cavities are increasing, the substance of the cells is also increasing. There is a whitish matter like dust that lines the cell everywhere: whether this is excrement or not I cannot say. While in this state I do not believe they change their caterpillar coats. They have but one state before they get their wings; therefore they have but one change, and thus differ from the common flying insect.

The wingless state cannot be called a grub, maggot, or caterpillar; it has more the figure of those of the apterous ? kind, having six feet of considerable length, two antennæ, with the projecting abdomen something like a louse, only a little rounder, and a shorter abdomen. It is of a light brown colour. When the fir-shoot has done growing and the buds are formed, then the little animals are ready to make their escape; each cell opens like the openings of the cone of the pine, and forth the animals come. When it comes out it crawls on to one of the leaves of the pine, and there it rests, and throws off its coat, or rather slips out of it, and leaves it on the leaf, with the skins of the feet as it were grasping the leaf. The little animal now begins to have the wings shooting forth. They appear like two little green knobs on the lateral and posterior part of the thorax. They soon come to their full size. The wings are green, but the body is of a darker colour than what it was before.

It is to be supposed that they now copulate and lay their eggs. Each of the parts of the fir-bud is a kind of capsule for the leaf, so that by having the eggs laid in it, either the egg or the young insect can be conducted to that which is to form the stem; and there it stimulates the stem to form itself in such way as to make a regular cell at the root of each leaf, while the leaf itself is prevented from growing, which makes this part of the shoot appear like a cone of the pine, and the young insect or eggs appear like the seed of the cone. The structure, appearance, and the different processes that go on in the part, would at first seem to be the natural process of the plant, not depending on a foreign stimulus; for, in the month of May, when the shoot is swelling and beginning to elongate, we find that it begins to swell as if inflamed; but when sliced down I could not observe the eggs.

Of the White Evening Moth. [*The 'Brown-tail,' Porthisia chrysorrhœa,* or *the 'Gold-tail,' Porthisia auriflua.*]

The white evening moth, the female of which has a [tuft of] brown hair at the anus, almost like a hair-pencil cut short, and which is easily removed, has some of the hair carried along with each egg as she lays them. I suspect that the mucus on the egg entangles the hair. There appears to be more hair deposited on the whole clutch of eggs than we see at the anus; therefore I suspect it grows in the time of laying. I caught one of these moths laying its eggs on the leaf of the 'paper-tree'[1] on the 8th of June.

Moths fly about in the dark, seek their food and see in the dark. Look at the eye of a silk-moth by candlelight, and you will see it shine in particular lights. As the eye of a cat [shines in the dark], so does the eye of a moth.

On the White Butterfly [*Pontia Brassicæ,* or *Pontia Rapæ*].

This insect comes forth in the month of May, and about the latter end of May the female is full of eggs. In 1790 I saw one about the middle of April; the winter and spring had been remarkably mild.

They have a crop like the common fly, &c. I found a chrysalis in the latter end of June, and the winged insect came out of its cell, July 2nd. Query, was this chrysalis of the same summer's growth, or of the last year's? If it was the last year's, then it was late, when we compare it with those above mentioned, that came out in April or May. Or, do they breed twice in the same summer? Or, do the first brood in the summer bring forth the second brood, and those that brought forth the first die? and when the first brood has laid the eggs, does that brood also die? I should think this most probable.

It would appear from Mr. Marsham's account of the inductions of spring*, that the yellow-butterfly [*Gonopteryx Rhamni*] is the earliest butterfly that comes forth; and that they are coming forth earlier now than formerly. This cannot be called civilization among them.

Of the Ant.

The natural history of the ant is very curious; they perform every function in life before they are complete; when complete they appear to be idle, only walking very gravely about. If so lame that they cannot walk, they are attended by those which are yet but workers.

They are both offensive and defensive animals; they make an attack, and they defend. I have put a large ant among some small ones, and they have attacked it. If they are disturbed, and you move the hand

* Philosophical Transactions, vol. lxxix. part 2.

[1] [The Paper Mulberry-tree (*Brucea papyrifera*).]

over them, they immediately draw in their belly under them, and rest on the back part of their belly, upright, with their trunk ready to defend or attack; and, if the finger comes within their reach, they immediately lay hold of it and bite.

They breathe air similar to other winged insects; it is seen in the abdomen. In those that have wings there is a good deal of oil or fat; for in dissecting them in water, a considerable number of small globules were seen rising from them and floating on the surface of the water.

When they have got their wings they still work, for I put some of them into a glass with some earth, and they burrowed; and I saw them busy in going down their subterraneous cells and bringing up the mould in their pincers. I also saw them carrying the egg or chrysalis like the common wingless ant.

Many of these flying ants are of a very pale brown. I suspect that when they get their wings they cast off their ant-coat, and get a new one, which is white at first, and becomes brown afterwards.

Of the Musca [Eristalis] tenax.

This fly lays its eggs on the dry sides of vessels, or cavities containing putrid animal matter in a fluid form, or on substances projecting above the surfaces of such fluids. I believe this is performed in the month of June.

The progress of hatching, the period of the maggot, and the continuance in the chrysalis state, are all very short. My gardener caught one about the beginning of June. I caught one on the 4th of April, 1790: the winter had been remarkably mild. About the latter end of June the young are coming forth, and then they are more in numbers. In the months of July, August, and September they are in great numbers. About the latter end of September they are getting into houses, especially out-houses, half insensible.

I caught one on the 20th of October, a female; its stomach was full, but it had no fat[1].

Of the Gnat [Culex pipiens].

This animal may be said to be an aquatic one while in the maggot or second state. They live in the water till they go into the chrysalis state; yet I imagine they breathe air; for, like the *Musca tenax*, they keep the end of the tail afloat, which is their trachea; but they differ from the *Musca tenax* in having considerable progressive motion in the water, although the power is seldom or ever used but when they

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[1] [Hunt. Prep. No. 596.]

are disturbed, and then they sink, or make to the bottom directly; and, as soon as the agitation in the water has ceased, they directly make their way again to the surface. When they move down they go with their heads foremost; and they ascend without changing the same position, moving with the tail uppermost or going backward. Their progress is by the alternate zigzag motion of their body. When not disturbed they hang by their tails on the surface of the water; and, when there are many of them, they make a pretty object. The end of the tail, which stands out from the end of the body, making with it an obtuse angle, has, I suspect, either some oil in it, or it can throw out a hollow cone, which, being filled with air, suspends the body; for, when the end of the tail comes to the surface, the water is repelled, not allowed to touch the very end. When not suspended by the tail, nor moving with their bodies, they slowly sink, and therefore are specifically heavier than water.

To ascertain whether they breathed air, I filled up the glass in which they were with water full to the brim, and then covered it with a piece of flat glass so that the surface of the water touched the under surface of the glass, by which means no air was opposed to the surface of the water: they immediately came to the top, but they could not be suspended, and in those attempts they soon died, being drowned for the want of air. When suspended in the water, there are some parts about the mouth or head constantly in motion.

The gnat can hardly be said to go into the chrysalis state, as in many other insects: it does not leave the water, nor does it enclose itself in a coat spun out of itself, but seems to be more motionless or less frisky, more coiled up upon itself, forming a round body with a globule of air on the back, which makes it swim. Its head-part seems to become larger and of a darker colour, and the belly, or what is commonly called tail, becomes rather less; yet in this state it has motion when disturbed, and sinks by its motion. I imagine that in this state new parts only are forming under the skin, not a change going on, and that, when completely formed, they emerge out of the old skin, leaving it swimming in the water, as it were hanging by the tail.

The *Aphis Abietis* also does not go into the chrysalis state.

Of Bugs [*Cimex lectularius*].

Query. How do bugs live? what do they eat?

They suck blood and fill themselves full. It is supposed there are some people that they do not bite, and others they do; but most probably they bite every one, but the bite is insensible to some. I once supposed that they did not bite me, but I now suppose they do. Going to bed at night I have observed them marching down the curtains and head of the bed: such when I caught and killed had no blood in them. In the morning I have observed them marching back, and all such I have found full of blood; and in a very large one which had got under my shirt at the shoulder I felt a something move, which I rubbed with my hand on the outside of my shirt, and immediately found something wet; and when I took off my shirt I found it was a very large bug. The shirt was stained for some breadth with blood, and yet no marks could be observed anywhere on the skin. The bugs I caught in the evening had no smell, when killed; which made me suppose that they had smell only when full of blood. I next killed them when full of blood; and then they also had no smell. This was in the month of August. The question now is, at what time do they emit the peculiar odour?

Of the External Characters of Insects.

The flying insect is, in common, made up of three parts, the 'head,' the trunk or 'chest,' and the 'abdomen.' But in some the chest is composed of two parts, which in such makes the whole body to be composed of four parts. The common fly of all kinds, the *Musca* (*Eristalis*) *tenax*, all of the bee-tribe, have the chest divided into two.

All of the flying-kind have six legs, which arise from the chest[1]; and in those where the chest is made up of two parts, the anterior part is smaller than the other, and it gives rise to the two fore legs.

Of the Senses of Insects.

It is more than probable that insects have all the five senses. We know that they see, that they feel and that they hear; for thunder, or the firing of a gun, or the ringing of a gong, or of a large brass kettle, will frighten bees. They certainly have taste; and it is most probable they have smell; for I think that I have led a silk-worm to different parts of a table by drawing a mulberry leaf before it; and, by shifting the leaf and placing it behind it, the worm has turned: but how far all this might be accident I will not pretend to determine. Whether the whole of that tribe are endowed with the five senses, is not easy to determine: it certainly is not a reason why the whole should have them, because one or more have; for, in the most perfect animals, we find one

[1] [This applies to all true insects.]

tribe where some species of them are entirely deprived of the sense of smelling, viz. the porpoise, although others of the same tribe [viz. the whalebone whale] have [that sense].

Of the Nourishment of Insects.

The nourishment of this class of animals, problably like that of all others, is, first the common food, secondly the store or reservoir of nourishment laid up while food was plentiful, and thirdly, part of the animal itself, as the wasting of muscles, &c.

The common food varies in different classes of insects. The store consists of a substance, like fat in some, but not of an oily nature; while in others there is a fat which is oily, as in the humble-bee. The wasting of parts [in its relation as a source of food, by absorption], is probably the same in all animals.

Of the Store or Fat.

All winged insects, as far as I know, have a store of nourishment laid up as gleanings out of the common food after having become blood. In the maggot or caterpillar it is hardly oil. This is somewhat similar to this store in most young animals; but in the full-grown it is a fine oil, in very small cells, like marrow in quadrupeds. This, like the fat in most other animals, is situated in every cavity or interstice of the body, and is most in quantity according to circumstances. It is most in quantity when the caterpillar is going into the chrysalis state: and, in those that live through the winter, as the common fly, female humble-bee, wasp, hornet, &c., it is largest in quantity in the autumn.

In the chrysalis state many parts are formed out of it, such as the extremities, parts of generation, &c. In those that go into a state of torpidity, the fat is wholly gone by the time the fine weather comes in. We need only kill a fly at each season to be sensible of the truth of this.

Of the Food of Insects.

The food of the caterpillar and maggot often differs very much from that of the fly-state in the same insect. Perhaps there are few insects which eat the same food when in the perfect or third state, that they did in the first. However, I believe the wasp and hornet are exceptions, for they seem to feed their young with what they eat themselves.

The food of insects, when in the maggot or caterpillar-state, is commonly very juicy, and they themselves are full of moisture. However, this is not always the case with the insect when in the second state;

for the maggot of the common moth [*Tinea tapetzella*] lives upon feathers, hair, wool, &c., which seem to furnish much water or a much moister substance, for they are as full of juice as any.

Of Digestion in Insects.

The food in many insects, and in the more imperfect animals, does not undergo so much change as in the more perfect; or at least not so much of the food is digested; wherefore they eat much more, and produce much more excrements, and that excrement is very much the same as the food when first eaten. This we find verified in the snail: the excrements of this animal appear to be nearly the same as when eaten. In fleas we find the same thing; also in the silk-worm, and perhaps in all caterpillars.

Of the Teeth of Insects.

All insects I believe are not endowed with teeth. Those that only suck, as the common fly, have none; yet some that suck have them, as the bee. But in the bee they are used as weapons of offence among one another, and as modellers of their cells, not as eaters. The teeth of insects are, I believe, always of a horny nature. They are commonly in pairs, and are placed laterally, opening sideways, as in the bee, spider, lobster, &c. They are of various shapes, some like two claws as in the grasshopper, which are more parts of offence and defence than for eating. They are placed externally like the bill in birds.

Of the Weapons of Insects.

Many insects, like many other animals, have weapons entirely of offence and defence; others have weapons for a compound use, for offence and defence, and for the catching of their food or prey. But those that have them for the compound use, when they use them otherwise than in catching their prey, do so generally upon the defensive, as, for instance, the grasshopper; for if a grasshopper be caught, it bites with considerable force. However, in the grasshopper it may be an offensive instrument among themselves. The weapons which appear to have no other use but for offence and defence, are such as the sting of bees. In those insects that have the weapons compound, both males and females possess them, both having the same [need and] mode of procuring their food; such as the grasshopper. This is similar to the lion- and dog-tribes; also to eagles, &c.

Those insects that have weapons of offence and defence, simply, such as the bee-tribe, have them only in the female. These instruments are similar to the horns of quadrupeds, the spurs of the cock, the poisoning teeth of vipers, &c.; but there is a singularity attending the possession of those weapons in the insect that is not in the other animals. In other animals these weapons of simple offence are either common to both male and female, or are peculiar to the male, so that there are more males in possession of such weapons than females. And in those animals where such weapons are common to both sexes, and are used for offence and defence, the males have them better fitted for action than the females. The tusks and claws of the lion, the tusks of the boar, the horns of the bull and ram, antlers of the stag reindeer, are all better fitted for action than those in the lioness, the sow, the cow, the ewe, the hind of the reindeer, &c. But weapons of offence are so peculiarly wanted by the male, that many males have them and the females not; such weapons are the horns of the buck, the spurs of the cock, the tusks of the horse; so far then the males have the superiority in point of offensive and defensive weapons; but this is not the case with insects, for the females possess the weapon in many kinds where it is peculiar to one sex.

Of the Heart and Blood of Insects.

The heart of the caterpillar runs all along the back its whole length. [When it acts] it begins to contract at the tail of the animal, and the contraction runs from thence to the head: it can be traced all along by the eye.

The circulation of the insect is probably very slow, if we may judge of the whole class by the motion of the heart in the caterpillar. In the silk-worm, for instance, the heart beats only 34 in a minute: however, I have known in the adult human the pulse as low, when in visible health; and this for many years. The blood in the winged insect must be small in quantity, for when we open any one, we hardly observe any moisture. But, as an insect has two active states, viz. the maggot, and the complete, or fly-state, we find the blood very different as to quantity in these two states. In the maggot or caterpillar it is large in quantity; in the fly-state it is hardly perceivable: this last circumstance takes off weight in flying.

Of the Circulation in Insects.

The circulation of the blood in the insect is in itself very simple; yet from our being very familiar with the most complicated, viz. that in the *Tetracoilia*, it at first might seem complicated.

Insects may be said to have neither pulmonary arteries nor veins, having but one simple circulation; nor can they be said to have one aorta, but many; all going out from the long canal of the heart. Whatever blood is sent out from the heart in the insect is prepared blood; therefore the arteries serve the purpose of the aorta; and the veins, both of the veins in common, as also those called pulmonary [in the *Tetracoilia*]; for the common veins have the blood prepared in them, serving the purpose of pulmonary veins in the insect.

I conceive that there is a great regularity in the vascular system in the insect, although it is not easily unravelled.

Of the Arteries.—The arteries would appear to go out laterally, in a kind of plexuses[1], and would appear to form the same on the stomach, &c.

Of the Veins.—The veins of the insect would appear to be simply the cellular membrane; but they are regular formed canals, although not such distinct cylindrical canals as in the quadruped, &c., nor branching with that regularity. They would appear to be, or to fill up, the interstices of the flakes of fat, air-cells, muscles, &c., and therefore might be called in some measure the cellular membrane of the parts[2].

Of the Respiratory Organs of the Flying Insect.

The organs of respiration of the flying insect answer two purposes; one, the purifying the blood, the other for flying.

It is probable that they are much too large for the first use; for, in the beetle they are much larger than in the fly, because it is much heavier in the body; therefore the beetle requires more of those organs to give it levity [and has wider and more numerous air-cells].

Of the Water Spider (Hydrachna).

Observing a small spider in the water where I had two cuttle-fishes crawling about, I took it out, and put it into [another vessel of] water; and it lived there very well for above two weeks. It laid its eggs and

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[1] [The parts here described answer best to the attaching muscles, or 'aliform ligaments' of Straus Durckheim, and to the entering sinuses, of the heart.]

[2] [Cuvier supposed the whole of the blood of insects to be limited to receptacles of this description, and consequently denied that they possessed a true circulation, or that the dorsal tube acted as a heart. The more accurate views of Hunter, based on the analogy of the already commencing irregularity and extent of the venous sinuses in the crustaceans, have been amply confirmed by the researches of Prof. Carus, on the 'Circulation of the Blood in the Larvæ of *Ephemerides* and *Libellulæ*.' See *Blutkreislaufes in den Larven netzflüglicher Insecten*, 4to. 1827. See my 'Preface to the Animal Economy,' p. 22; and 'Physiological Catalogue,' 4to. vol. ii. p. 31.]

spun its thread about them in the water, and then died. The colour of the spider was dark, with yellow dark sides, with a yellow back and belly.

The silk with which spiders cover their eggs is from the mouth, as in the silk-worm ; not from the anus like that with which they spin their web.

Of the River Crawfish [*Astacus fluviatilis*].

The freshwater crawfish spawns in June ; casts its coats in July ; the new coats becoming hard in a day or two.

The male is like to kill the female, about October, with lewdness ; so that it is most probable they copulate about that time. If so, then they go with egg all the winter, as I have suspected the snakes to do.

Their four small legs have claws like pincers at the end, with which they lay hold of bodies for their progressive motion.

Economy of Earthworms [*Lumbricus terrestris*].

Earthworms eat vegetables, for they are found in their stomach, but it is seldom that they are seen eating. They, not having teeth, will confine their food to such kinds as do not require dividing. Their principal food would appear to be earth, from such vast quantities being found in their stomach and guts ; and the vast quantity thrown up at the mouth of their holes.

After a shower they come up from the earth and lie flat upon the surface, having their tail within the hole, and they eat the earth which is quite on the surface. Upon the least motion of the earth, they immediately withdraw themselves into the hole. A worm of one foot long can contract in length to about three inches ; so if they leave three inches within the hole it is sufficient to bring in the whole body, and it has nine inches out. They go vast depths into the ground. I have found their holes leading down six feet in a loose sandy soil.

September 30th, 1774, I observed a large earthworm upon the ground with a white spot pretty near to the anterior end. On the same morning I observed two worms in copulation. They had come more than half out of their holes, which was about half a foot from one another ; they lay alongside of one another ; the head of the one beyond the ring of the other ; they had turned upon their side, so that the belly could come in contact. They had fast hold of one another, but in what way I cannot say ; whether by an endeavour to form a vacuum between them like the ends of a leech, or by laying hold of one another by their claws on the belly, with which they can hold fast to any thing they have a mind to hold; as is evident in their keeping hold of the side of the hole in the ground, so as that the animal will break before it can be pulled out.

This contact was so strong, that they did not separate upon being cut through at the part which entered their holes, and also allowed themselves to die in one another's embraces when put into spirits of wine. At the annular part, in the angle between worm and worm, were several white spots, which appeared like very small drops of milk, which were removeable with the point of a pin.

Worms have four rows of claws running from one end of the animal to the other, which are in pairs; each ring having eight claws or four pair. They are placed on the belly, and are pointed backwards; they do not appear to act as feet; but when the head is moved forwards, they hold till the tail is pulled forwards.

They are composed of rings which serve as joints. At the union of every two rings there is a transverse partition which fixes this part to the intestine, so that the whole cavity of the worm is divided transversely into as many chambers as there are rings (excepting at the anterior end). These valves or diaphragms act as so many fixed points, and always keep the external and internal parts properly together, or in apposition: these diaphragms also make so many constrictions on the intestine, which gut swells between them. At the anterior end the external part of the worm is connected to the œsophagus by a soft spongy substance: then the partitions begin, a little way before the first heart.

The œsophagus, stomach, and intestine is one straight canal running from one end of the animal to the other. The œsophagus and intestine swell into bags or kind of aneurisms between each diaphragm. The stomach is composed of two parts; the first, a pretty large bag, serving as a kind of reservoir; and then a gizzard part, or a circular ring, which is strong and thick, capable of using considerable force upon the food, and serve in the place of teeth, as in the fowl.

The Copulation of the Earthworm.—The earthworm is a copulative hermaphrodite. They copulate in the month of October*. They come, in part, out of the ground, having their tail remaining some way in the hole, so as to be able to make good a retreat. The fore part of the body lies along the ground, and this protruding part is elongated or shortened according to the distance they are from each other; and they move this exterior part round about the enclosed part, as round a centre in search of a mate; and when they meet with each other and touch, they throw themselves on one side to oppose the under surface to each

* They also copulate in the beginning of the summer.

other. Sometimes they are at such distances from one another as not to reach, without one coming entirely out; and sometimes they are both out.

This need only take place where there are but few in number. Some one shall come out when there is no mate near to engage and be engaged. They do not oppose the same parts to each other, as head to head, and of course tail to tail, but in contrary directions, by which means the male parts of each are opposed to the female of each. Some way behind the anterior end there is an annular part which belongs to one of the parts of the sexes, and, before this, about an inch, there are two orifices, one on each side of the under surface, which I suppose belong to the other parts of the sex. They copulate before they are above one third or fourth grown in size.

They generally come out of their holes about nine o'clock in the evening; and in the morning, by daylight, we find them united, and by ten o'clock they are all retired again to their holes. When it is cold, or when there is a hoar-frost, they are not to be found in this act. They continue in the act for perhaps about twelve hours, but whether this time of retiring arises from the influence of the time of day, or by being disturbed by what is passing during the day, I will not say.

I placed marks to several in the act, to see if the same repeated their operations next morning; but they did not, although there were many that were in the act.

Geographical Distribution of Animals.

The locality of some animals would make us believe that their formation was of late date when compared to the world; or else that the present face of the globe was very old or original. The first we can hardly suppose, and as to the last "very old," if that was the case it would still show that the origin of animals was progressive and of course local.

It is a curious circumstance in the natural history of animals to find most of the northern animals the same both on the Continent of America and what is called the Old World; while those of the warmer parts of both continents are not so. Thus we find the bear, fox, wolf, elk, rein-deer, ptarmigan, &c., in the northern parts of both. However, birds are not to be considered as entirely explanatory of any theory of this kind, as they can so easily move from place to place: yet if we can show that it is upon the same principle that the same animals occur in the northern parts of both Continents, one fact then explains the other.

The reason why the same animals are to be found in the northern parts is the nearness of the two continents. They are so near as to be within the power of accident to bring the animals, especially the large ones, from one continent to the other; either on the ice or even by water. But the continents diverging from each other, southward, so as to be at a very considerable distance from each other, even beyond the flight of birds, is the reason why the quadrupeds [of those southern regions] are not the same [in both continents].

It is reasonable to suppose that those animals were natives of either continent, and of the northern parts, and that those animals which are spread over all the old continent, but domesticated, such as horses, asses, cows, sheep, some deer, hogs, &c., were animals of the more southern parts, and that their universality in the colder parts is only of modern date.

Most animals, probably, have the disposition to keep to their place either of nativity or adoption. Those that are not animals of passage, of course keep to their place of nativity; but this is much more confined in some than in others. A pigeon [the Rock-pigeon, *Columba livia*, e. g.] keeps to the very spot, viz. house or rock, even to the same hole; a dove [the Ring-dove, *Columba Palumbus*, e. g.] keeps to the wood, but not to the same spot or tree; therefore, it wanders a little. But birds of passage, I believe, only keep to their place of adoption, and this very strictly. A swallow builds, if allowed, in the same nest or same corner of a window. Thus animals which have taken up a residence, whether their native one as in the case of the pigeon, or their adopted one as in that of the swallow, crow, magpie, &c., keep to the same place. The circumstance of adopting a place, shows that the young of these do not keep to the same rules, only those which keep to their place of nativity.

Some animals burrow for protection, habitation, &c., as the badger; others for their livelihood, as the mole, and probably the mole-cricket.

OBSERVATIONS ON PHYSIOLOGY.

ON LIFE AND THE LIVING PRINCIPLE.

Analogy of Life to Combustion.

IN the works of Nature, where we see a similarity in principle, or effects produced from similar causes, it is reasonable to suppose that they [those works] are similar in their great principles, and therefore may arise from one cause. If this is reasonable, we see that what we have been saying with regard to fire and air in the Introductory Treatise, may be applied to the lungs. There we explained in what manner air has an effect upon fire; but, without being able to explain this, we see that air, some way or other, is of great service to fire. It is from this that we draw the analogy; and what we want to do here is to see if the explanation of the one will apply to the other.

I would consider Life as a Fire, or something similar, which might for distinction's sake be called Animal Fire.

Like common fire, it wants a constant supply, without which it would be extinguished; and, like common fire, it seems to be let loose in the lungs, so as to be fitted for animal life, before it sets out on its great office: and this letting loose of the animal fire seems to depend upon the air, as much and in the same manner as common fire. So that, instead of something vivifying being taken from the air, the air carries off that principle which encloses and retains this animal fire. I do not mean real and actual fire; but something that is similar, and is effected and brought about much in the same manner. And by understanding the one, we are led, in some measure, to the knowledge of the other; so that the aliment we take in has in it, in a fixed state, the real life; and this does not become active until it has got into the lungs; for there it is freed from its prison[1].

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[1] [Both Hippocrates (Opera, tom. i. p. 112) and Harvey (Exercit. 71) were influenced by this analogy of the animal operations to the consumption of bodies by fire, and identified the vital principle with that element, as the *Calidum innatum, &c.*]

Living Principle, its union with Body.

The Living Principle is not simply diffused, but it is combined, or makes one of the constituent parts of the whole, and the variety of actions arises from the construction of the parts. I should call the harmony between one part of the body and another 'vital harmony;' as, for instance, the harmony of the blood with itself; the blood with the vessels; one part of the body with another, where the connexion is only contact, which parts can be shifted without injury owing to this harmony.

Living Principle, its Nature and Degrees.

A young animal has the Living Principle more lively, but perhaps not so strong, as an old one. Injuries that do not affect the whole, are sooner repaired: a broken bone unites sooner; a cut unites or heals sooner. But the whole living principle is sooner destroyed: young animals cannot endure hunger and cold so long: pain throws them into convulsions, so as to destroy life itself.

Whatever Life is, it most certainly does not depend upon structure or organization[1]. In contradiction to organization being a cause, we find in general that the least organized are the most tenacious of life. Thus we find that, in general, the most imperfect animals are the most difficult to be killed, when the actions of the parts are stopped upon which life is continued. But this is not constantly so, therefore peculiarity of organization is not in the least necessary.

A still stronger proof than the one above, that organization is not essential to Life, viz. that different organizations make no difference [in respect to life in the abstract], is, that different animals with the same organization are very different with respect to their being easy or difficult to be killed by the stoppage of those operations that continue life. For instance, an eel will live out of water for many days, while a mackerel dies instantaneously: a carp will live many weeks out of water if kept in a moist place. These differences only respect respiration; which, however, is essential to life, although not so much so in some animals as in others.

A very great difference will take place in the same organization with respect to food; a sparrow, a linnet, &c., will soon die, if not regularly supplied with food; while an eagle, hawk, swallow, &c., will live a great while without a supply. The food indeed is different, but the

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[1] [I leave these passages without comment: they may serve to throw light on the often mooted question of Hunter's real opinions on the subject.]

construction of the two animals is exactly the same, and therefore depends upon some peculiarity in the 'Principle of Life.'

Living Principle illustrated by the mutual attraction of Parts for union.

How do parts of a living body grow into one another? I should suppose that this is entirely owing to the simple Living Principle; that whenever two parts which have an affinity—which are sensible of one another—come into contact, and the impression each receives is the same, the effect on both must be the same, and the desires from such sensations the same, like a kiss. The result of which is, that they come into mutual apposition, vessel to vessel, and the two become one substance; all similarities on each side attaching themselves together.

The Living Principle appears to be the same[1] in all animals; for whenever two parts of the same animal, or two parts of different animals, come into contact, they unite into one; and if both have connexion with the heart or hearts, each part is in some measure supplied as before; only, that each part is capable of supplying its neighbour. But if either part be deprived of its heart, either before or after its union, that part is immediately supported by the other, and its Living Principle is supported; but nothing more is done; for, whatever disposition either or both had, they still retain that disposition and acquire none of the other. For instance, a spur of a cock still continues to grow a spur when transplanted to the comb. Nor does the stock on which a sucker of a tree is inserted seem to be altered in its disposition. Each with regard to disposition seems to be a perfect Being, with one Living Principle.

Of Simple Life.

We find this principle called 'Simple Life' much more in some animals than others. This difference is not confined to peculiar classes of animals entirely, although it is so in some degree. I believe it is pretty equal in all the *Tetracoilia*. Few, if any, live long after being deprived of the action of respiration, or of communication with the brain; life, indeed, is then of but very short duration. However, as none of this class are uniformly constructed throughout, there being some parts which have a greater dependence upon their connexion with the first principles [of life] than others, we find that 'Simple Life' is of much shorter duration in those parts than in those which have not this con-

[1] [The same in essence, not in degree] is here meant.

nexion. For example, the voluntary muscles lose this [simple life] much sooner than the involuntary. This is carried still further in such involuntary parts as are mere appendages of the animal, among which the secundines may be reckoned. I find that the umbilical artery and veins of a calf will contract, after being cut, four times twenty-four hours after the death of the animal, while the other arteries of the same calf will not contract when cut in the same manner, after it has been dead twenty-four hours. So far we find a very material difference in parts of which the construction and use are the same. This experiment was made in the winter of 1780. Probably they could not live so long in the summer. However, both the experiments were made at the same time, which shows the comparative powers of these two vessels of the same animal.

This principle of simple life is much more universal in one class of animals, viz. the *Tricoilia*, than in those we have been speaking of. It exists, I believe, universally through the whole of this class [*Tricoilia*], in a much greater degree than the above [*Tetracoilia*]. The *Tricoilia* have also some parts of their body which are possessed of a greater share of it than others, viz. the voluntary muscles, which have much less of it, or lose it much sooner, when deprived of their sensation, than the involuntary [muscles do]: so that this class of animals is pretty uniform one with another, as is the case with the first, only they have more of [irritability or ‘ simple life ’]; but we have reasons to suppose that they have less of the sensitive [life].

In another class of animals, viz. the Fish, which is inferior to the last, this principle [of Simple Life] is not nearly so uniform through the whole tribe as it is in the two above-mentioned classes. We find some fishes dying instantaneously upon being deprived of the sensitive life, or that upon which the sensitive immediately depends, viz. proper circulation. Such is the case with mackerel upon being taken out of water; while others will live for a considerable time when all sensation is gone, and when, of course, there is a cessation of all voluntary motion: such is the case with the eel, when either taken out of the water, or when its head has been cut off, or its heart taken out. There is, then, a great inequality in the same class of animals with respect to this principle. I shall not at present pursue the subject into other classes of animals; the above three classes, with the variations they admit of, are sufficient for the explanation I at present can give.

There is nothing in the nervous system, that I know, that can give any light on this subject; although it is possible that they [Simple Life and Nervous System] may be immediately related, or that some other principle may be the original cause [of Simple Life]. That there is another principle [or cause] is evident and demonstrable; this is the blood. But whether this fluid is immediately concerned, or is a remote cause acting upon the nerves, may not, perhaps, be easily determined.

Let us now trace this cause by comparing the bloods in [the above] different [classes of] animals, and see if, where the blood is similar in any two dissimilar animals, the principle above mentioned be similar; and, if so, in what respect the two bloods are similar to produce this similar effect. In the first class [*Tetracoilia*] the motion of the blood is extremely [rapid and the blood is] perfect; and this perfection depends upon the single circumstance of its having been thoroughly exposed to the external air by means of the lungs; so that none of this kind of blood goes to the body but what is truly pulmonary [in the sense of having circulated through the lungs]. In the second class [*Tricoilia*] the blood has not this advantage; the construction of the parts upon which the motion of the blood depends will not admit of it: and we find the blood passing to the different parts of the body very imperfect in this respect. It is composed of a mixture of pulmonary [*i. e.* arterial] and venal. So far these two [classes of animals] are not similar; and we observed that they were not similar in the affair of the continuance of Simple Life, when deprived of the sensitive, and of the motion of the blood. So it would seem from this view, that the greater power of Simple Life in the one over the other was owing to an imperfection in the blood; but, most probably, this is not the case, as will be mentioned hereafter.

Let us see how far the third class [*Dicoilia*] will throw light upon this subject. The mackerel and the eel are exactly of the same construction as far as relates to the motion of the blood; therefore, from the mere construction of the parts upon which the blood's motion depends, no argument can be brought to bear. We find that a mackerel loses the Simple Life immediately, whether it be deprived of the blood's motion, or be deprived of perfect pulmonary blood; either of these causes having the same effect. The eel retains the Simple Life for a considerable time when, either deprived of the blood's motion, or when deprived of the perfect pulmonary blood. Hence we might conclude that this principle of Simple Life does not require perfect blood, and therefore will exist a considerable time without blood at all. And it will follow, that an animal which has a superabundance of this principle, will have, in the same proportion, less need of a perfect blood or even blood at all, and will retain the principle of simple life a much longer time than those who have less of it and more of the sensitive life.

Do animals which are easily killed sooner putrefy than those that are not? A mackerel, for instance, which dies the moment it is taken out of the water, also putrefies very soon: Is this circumstance owing to the first? Does an eel, a turtle, or a snake, &c., which are very unwilling to give up life, keep a long while after life is gone?

Loss of Simple Life.

A young man, aged about twenty, came to St. George's Hospital for consultation about his leg and thigh. They were much smaller than those of the other side, had no motion in the ankle-joint, and but very little in the knee. The limb hung like a motionless body: it was very cold; while, with the same covering, the other limb was warm. In the winter he had chilblains all over the affected foot and leg, which were very painful; for he had sensation in it[1]. He had some motion in the thigh-joint, and the little motion in the knee-joint seemed to be owing to the long muscles of the thigh having some power at their upper end.

Degrees of Simple Life.

Animals in proportion to their simplicity have the Simple Life in a much greater perfection than the more complicated and perfect. All the natural functions go on with more regularity, and their powers are more. They can make up losses much better. Our simple life is much more confined, and can do much less for the body in case of accidents.

Is that principle we call 'Habit' in any way akin to Simple Life, or is it a kind of substitute?

Simple Life is in proportion to the imperfection of the animal: even in the most perfect classes of animals it decreases as the animal becomes perfect. Perhaps this is owing to a want of habit in it; for, as the sensitive life increases in the ratio of perfection, it takes off from the employment of the other principle, which is much less the case in the more imperfect animals. Quære, How is it in an Idiot?

Action adverse to Simple Life.

Simple Life is much stronger in vegetables than in animals; for a vegetable, when removed, will live the first year, but [sometimes] die the second. This is owing to the original life still existing, but the roots are not capable of keeping up its continuance. If Simple Life had been of as short duration as in animals, it [the plant] would not

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[1] [An interesting case of affection of the motory nerves and not of the sensory; and explanatory of the meaning of Hunter's 'Simple Life,' which seems synonymous with the 'Irritability' of Haller.]

have continued its growth for many days or hours. Its death is generally in the summer, when it is necessary to have an increase of life; but the roots being unable to procure it, it dies. It has just life enough to keep it longer alive in the winter state. This is similar to lizards which have been in the cold and are very weak. A lizard which would have been capable of living a month in such a weak state, and would show but little alteration in the cold, would die in an hour if brought into a warm room. It would seem as if a certain quantity of Simple Life was necessary to support the acquired life, or that life which depends upon particular circumstances. Some trees have much less of this life than others; for, in them, they are not able to shoot forth the first year.

The more complicated a machine is, the more nice its operations are, and, of course, the greater dependence each part has upon the other; and, therefore, there is a more intimate connexion through the whole. This holds good in society. It also holds good in the animal economy. The most perfect animals cannot be hurt in part without the whole suffering, while the more imperfect may be considerably hurt without the other parts suffering much. Thus we find that a man cannot lose a leg without the whole frame sympathizing with the injured parts, as if conscious of a loss; while a frog appears to be but little hurt. A snail, lobster, lizard, &c., can lose many parts which will be restored again. A polypus is still less hurt by amputation; for a new animal arises out of the wound or cut. So far we find a gradation from the animal to the vegetable.

Bodies which have a living principle can be acted upon by mechanical or chemical principles; but not by such a process as the fermentative, that is, they have not fermentative powers in themselves.

The act of freezing, simply, does not kill either vegetable or animal; it is the quantity of cold that kills. A vegetable that cannot bear the cold of 50° dies, although it is not frozen; a vegetable that cannot bear the cold of 30° or of 20° dies, although it may not be frozen before it dies, but will be frozen after; which will give the idea of its having been killed by the frost; but a vegetable that can live in a cold of 10°, may freeze at a cold of 15°, but will not die[1].

Degrees of Excitements and Sedatives.

We have natural actions; then stimulus, or increased excitement, to perform the same action; and then irritation, which is to perform

[1] [This assertion needs experimental proof, *i. e.* of the actual change of the tissues consequent on being frozen and thereby showing the fact.]

a new action; which is two removes. We have actions, then sedatives, which is a diminution of either natural or acquired action, and which is the opposite to stimulus: but we have not a something that shall produce indolent disease, which would be the opposite to irritation.

Stimulus is either mediate or immediate. The mediate often arises from the immediate. The immediate is mostly local, the mediate mostly constitutional. Every part of an animal that acts from impression, acts from an instinctive principle. A specific action in the body is similar to an abstract idea in the mind; it is separating and combining. When a morbid poison is applied to an animal that is not capable of taking on the [specific or poisonous] action, from what does this [incapacity] arise? Is it from the animal not being susceptible of the irritation? Or is it from the vessels not being capable of taking on the action?

Perfect health in every constitution requires for its preservation a regular influence or application of every natural thing. But this can never be obtained; for, from the changes going on in the natural surface of this globe, and the natural predicament in which it stands with respect to the heavenly bodies, it becomes affected; all becoming either predisposing, immediate, or contaminating causes. Thus, damp situations produce agues, or become a disposing cause to this disease. Dry or wet weather, the seasons, the situation respecting the sun and the moon, become an immediate cause by hastening on the action of the disease.

Every motion in matter produces waste; whether it is a mechanical motion, as from impulse of any kind, or a motion within itself, arising from an internal power of action, as in vegetables or animals. The supply in the first need not be of the same species; although the better, if so: but the supply in either the vegetable or animal must be of the same [vegetable or animal] nature.

Animal Heat.

Animal heat is hardly to be accounted for upon any principle that we know of, excepting the decompositions and combinations that often take place in the body.

The quickness of both [causes of animal heat] is very strange. James Campbell, from being excessively hot, would become almost at once extremely cold; much sooner than he could have done if his head had been struck off, and left to cool, and in an instant would become hot again.

The injections of nitre and ipecacuanha into the blood of animals show this quick transition from the one to the other. See my Experiments[1].

[1] [Where? (asks Mr. Clift.)]

The new combinations cannot be in every part of the body, as Dr. Stephens supposes; for that combination will go on in the greatest cold as well as in the greatest heat, and will produce the same heat in both. If this were true, then we should never be cold. But we find we may become so cold as that a part shall mortify. I do not imagine that animal heat arises from putrefaction, or from actions at all of the putrefactive kind; but from the chyliferous fermentation in the stomach, the sanguiferous in the lungs, and [the molecular in] the vessels in general in the body[1].

The heat of an animal cannot arise from respiration [alone]; for no animals respire so freely as fishes[2]: yet they generate very little heat, but when called upon [as in a freezing mixture], and then their powers of respiration must be very imperfect.

On Respiration.

Every part of an animal so exposed to the air as for the blood to be affected by it in such manner as to support life, may be called Lungs, or Respiratory Organ; but what is commonly understood as such, is an apparatus formed for that purpose, as a distinct part of the animal. But I conceive it very probable that there are animals so simple in their construction as not to require a peculiar structure for this purpose. I even know there are many so constructed, where an apparatus of this kind could not be applied, such an apparatus not according with the other parts. Yet I do conceive that in such the application of air is as necessary as in those where an apparatus is formed; but where there is a distinct respiratory apparatus, there must be other corresponding apparatuses.

Where there is such an apparatus, we find it admits of forms fitted for the different modes of respiration; yet all are included in the terms *Branchiæ*, or Gills, and *Pulmones*, or Lungs. But there should be a generic term, admitting of divisions into species, so as to be characteristic of the orders of animals to which they belong.

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[1] [In a bat the animal heat can be raised or depressed at pleasure, say from 50° Fahr. to 65°, and inversely, merely by accelerating or retarding respiration: which seems to show that where the whole constitution is adapted for a high temperature, combined with the faculty of losing it by torpidity, the animal heat may be generated by the respiratory independent of the digestive process; but as circulation is directly as respiration, the change of the blood in the capillaries may also assist.]

[2] [The visible movements of respiration in fishes are stronger and more frequent, in reference to the denser medium to be moved, but the actual amount of respiratory change is less than in the warm-blooded animals that breathe the air directly. A truer view of the breathing of fishes is taken in the next paragraph.]

Without a collecting and a motion of the nutritive juices, I can conceive there can be no respiratory organ; for I find that the different circulations in the different orders of animals, as far as I know, are so connected with different kinds of lungs, as for either system not to be intelligible alone. For, first, the different circulations cannot be described without including the respiratory apparatus, as this makes a portion of the circulation: nor will the mere structure of the lungs in different animals explain their full purposes: and as their whole use is upon the blood, and they are thus connected with the circulation, it is impossible to understand the one without the other; and this so much so, as to make it difficult to say which ought to be described first.

In animals where there is no circulation there can be no lungs; for lungs are an apparatus for the air and blood to meet, and can only accord with motion of blood in vessels. But where there is no circulation, yet we must suppose from analogy that the air affects the juices that are to carry a continuance of life and support to all the parts of the body*.

As the lungs are to expose the blood to the air, they are so constructed as to answer this purpose exactly with the blood being brought to them, and so disposed in them as to go hand in hand. The lungs in all animals are therefore placed near the heart, because it is the circulation only that they are concerned in.

The immediate action which puts the lungs into use is called 'breathing,' and this action is commonly performed by the surrounding parts, being a motion of dilatation, which produces or is called 'inspiration;' and of compression, which produces or is called 'expiration:' these motions of course are alternate†.

The respiratory organ, which must be considered as an appendage to the heart and vascular system, is so constructed as to allow the blood to be placed in such circumstances with respect to the external air as to give or receive some influence from it.

In the most simple animals, and such as breathe water, the whole

* It may be observed that the *fœtus in utero* is a contradiction to this; but we must suppose that the effect of air in the lungs of the mother is conveyed to the fœtus. But the respiration of the fœtus in the viviparous from an egg cannot be so easily accounted for, since there is no communication with either the mother or external air: but the egg in the oviparous would seem to be in the same predicament, yet I know they will not hatch without air. It is probable that all those animals within animals [*Entozoa*] are similar to the viviparous from an egg.

† Some animals do not sweat by the skin; in all these we find that their breathing becomes much quicker in warm weather or from exercise than what it does in those that sweat freely. They generally breathe with open mouths, viz. dogs, sheep, goats, oxen, fowls, &c. &c. This would hint as much as that the sweat and breath were nearly the same.

apparatus is to have a considerable quantity of very vascular surface brought in contact with the medium in which the animal lives.

In the air-breathing orders above fish, there is a simple bag, very vascular, for the reception of the air, and this is divided and subdivided as we proceed towards the more perfect animals, till at last the cells are infinitely small.

The lungs may be considered, respecting their blood-vessels or circulation, as similar to a gland; for the blood sent to them is not for their own proper use entirely, and indeed only a very small portion of it is for their own use, the larger portion being intended as a secretion from them, as also to receive.

The lungs may be called the Spring of Life; I conceive them to have two powers, one to receive, the other to give. I should consider them giving to the air what was rendered useless or detrimental as a constituent part of life; and exchanging it for that which it had lost, the essential part.

The minute division of the lungs into cells, the arterial and venous system ramifying upon the surface of those cells, and of course the whole of the blood passing through them in every circulation, with the loss of life upon the missing three or four breathings in the most perfect animals, show the great nicety that is required in the due properties of the blood for the life of those animals. This nicety is not near so great in many of the less perfect animals. The *Amphibia* have not this minute division [of the lungs]: the whole of the blood does not pass through the lungs; and they can live a considerable time without breathing. It is still less essential in the more imperfect animals, such as fishes, and still less so in some fishes than in others, such as eels; and these live a long while out of water.

What proof is there that respiration continues life throughout the body? and how come the *Amphibia* to have so great powers of life with so little respiration? Whatever the effects of respiration are, such effects should keep pace with the cause. There is reason to presume that heat has some natural connexion with the respiration of air; for the degree of heat is in proportion to the degree of respiration. From the chemical change produced on the breath, is there not reason to think that one purpose of respiration is to produce a chemical change on the blood? Expired breath is loaded with fixed air or aërial acid [carbonic acid], and this has been proved by the French chemists and by Mr. Muire to be a compound of charcoal [carbon] and vital air [oxygen]. It would appear as if charcoal were an excrementitious part of the blood separated by combining with vital air.

Lungs that are full of blood and of a dark colour soon become florid when exposed to the air. The liver the same. This shows that the influence of the air can act through the coats of the vessels.

When I was injecting the lungs of a man, the injection did not run freely; I then inflated them, and found that the injection immediately ran with freedom.

I find that in the human lungs there is a thin cartilage at the angle of inflection of two branches [of the bronchia], where it is membranous both in the trunk and in the two branches.

The cells of the lungs seem to increase in size the further from the trunk, or trachea; so that the trachea and its ramifications bear no proportion to the cells.

It is impossible for the lungs to be so collapsed, while air is excluded the chest, as to obstruct mechanically the passage of the blood through them; and, if that were really the case, there never could be dark blood in the left side. For if there is a collapse, then there is no motion of the blood: all stands still. If removing the collapse be the essential thing, or what is absolutely necessary in the recovery [of drowned or asphyxiated persons], how have so many recovered where such attention has not been used?

When an animal dies whose circulation goes on through the lungs after respiration ceases, the collection of blood in the two ventricles is not exactly of equal heats, the right being warmer by one or two degrees than the left; and if an animal dies while the lungs are inflated along with the actions of the heart, where the blood in the right side is dark and the left red, the heat in the right side will still be greater: but, upon waiting five minutes, the left will be several degrees warmer, so that the right either loses its heat faster or the left generates heat. But this last part which I am going to relate has not been tried, when both sides were black, with that accuracy as the first; viz. which side of the heart ceases to act first when respiration is kept up, and which side begins first upon inflation.

Coleman[1] asserts that inflating the lungs alternately, and the heart acting, there is no change of colour in the blood of the left auricle, which cannot be true.

The only time that water can possibly get into the lungs, in drowning, is just at the last inspiration, which is an inspiration of extreme necessity.

The proportion of the blood contained in the two sides of the heart after a violent death, as by drowning, hanging, or suffocation from bad air, is commonly as 12 in the right to 7 in the left side. But, in

[1] [Professor Edward Coleman, of the Veterinary College; the work referred to by Hunter is "A Dissertation on natural and suspended Respiration." 8vo.]

hanging, if the lungs be kept distended in the time of hanging, then the left will have the largest quantity.

As the right side of the heart acts longer than the left, one might suppose that the left side should be the fuller; but I imagine that its action at this time is with so little force, that no blood is sent to the lungs.

As most of the blood in the body will always be rather conducted to the larger vessels and of course the heart, and as the right side contains 12 where the left contains only 7, does this not support a presumption that the proportion between the [blood of the] body and [of the] lungs is as 12 to 7? However, I should think the body [would have] much more.

The blood being in the larger veins and heart is a proof that the arteries act longer than the veins; and that the capillary veins act longer than the larger ones, or even than the heart; and the blood in the left ventricle will be the florid red.

By letting the blood out of the heart when much distended, it acted. Was this produced from emptying it, or from wounding it?

What is the connexion of muscular action with respiration? For it is well known that violent exercise excites respiration to a great degree.

The true amphibious animal, if such there be, is such as can breathe both air and water. The turtle, frog, &c., breathe only air; and are such as can live without breathing for some time, similar to many animals that never go into the water: but they live in and by the air. If these animals are amphibious, all animals are amphibious, although in a less degree; for all animals can live under water for some time, viz. as long as they can refrain from breathing; longer than which no animal can live.

The knowledge of the differences in the circulation in the different classes of animals, has gone no further than [as they exist in] the Mammalia, the human subject, the fœtus in such, and what are called the Amphibia: and, of course, every piece of reasoning respecting the circulation, which includes respiration (these being immediately connected), has been brought in to explain, upon those differences, the other variations between the two classes of animals. But [the circulation] cannot be a cause of such variation; because other classes of animals shall have the similarities [in regard to circulation] of the one class, while they shall have the varieties of the other[1]: and, in some classes of animals, where the circulation and respiration is the same in the whole class, yet the heart in some shall be like the human, and in others it shall be like the amphibia[2].

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[1] [Birds, for example, have the four-chambered heart and perfect respiration of mammals, but have the oviparous generation and the general plan of structure of Reptiles.]

[2] [Crocodiles, for example, have the four-chambered heart; but with an arrange-

Loose Notes and Queries on the Blood.

I think it is probable that not anything that is mechanically diffused through the blood, can agree with it, and I conceive that it will most probably kill. Thus air, milk, &c., kill in very small quantity. Therefore whatever agrees with, or does no hurt [to the blood], must be in solution in it, although at the same time every thing that may be in solution may not agree with it.

What would be the consequence if a part of the circulating blood was deprived of life, as from a part being struck with electricity? But probably a part cannot be struck so as to kill the blood only; the whole must die.

Arterial blood becoming dark in the living body by rest, as when extravasated, and not in a vessel, shows its living powers.

There appears to be a greater variety in the quantity of red blood in birds than in any other known animal: some have little, others a great deal. It is also thrown more on particular parts in the bird, because they have two modes of progressive motion; therefore as the one [by the wings] or the other [by the legs] predominates, so is the red blood thrown.

On the Circulation.

In many animals, especially the more perfect, the nourishment, or whatever is taken into the system, is taken up and carried from the stomach and other parts, by the absorbents, to an engine called the heart; from which it is thrown out into tubes which conduct it to every part of the body, and thence it is again returned to the heart by other vessels.

An animal body has in general been considered under the idea of an hydraulic machine, because it appears to be almost wholly composed of tubes in which fluids move. I shall not at present enter into all the different opinions concerning the uses of these tubes, especially of that system called arteries, how they are variously affected, and how they produce their various actions according to the different stimuli either of health or disease; but shall only give some general ideas of the most immediate uses of the three different systems of vessels.

The vessels in general would appear to have more powers of perfecting themselves, when injured, than any other part of the body; for their use is almost immediate and constant, and it is they which per-

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ment of the arteries permitting the mixture of venous and arterial blood, as in the tortoises, lizards, and lower reptiles.]

form the operation of restoration on the other parts, therefore they themselves must first be perfect. They would seem to have more of the Polypus in them than any other part of the body. This is, perhaps, more in the absorbents than in the arteries or veins, for we can conceive a part injured by accident, and, as it were, standing still for a little while; but we see ulceration going on very rapidly, which proves an immediate formation of vessels for absorption.

The first two, viz. the arteries and the veins, belong immediately to the motion of the blood, or the Circulation. The arteries carry the fluid from the general reservoir, the heart, to all the different parts of the body, and the veins bring it back again.

Of the Arteries.

The arteries, which carry the fluid to all the parts of the body, constantly dispose of part of that fluid in the different operations of the body, according to their different affections; adding to the whole while growth is necessary, making up losses where the old is either improper or destroyed, and throwing out of the direct line of their motion parts of that fluid, which, according to the various affections and actions of these arteries, become considerably altered in this passage, called secretions.

The juices so secreted are intended for various purposes in the machine: some for stimulants, as the bile; some for mechanical purposes, as the tears, synovia, saliva, &c.; some for a store of nourishment, as the fat; while others are thrown out of the body as useless, because they have already performed all their purposes, as the urine, &c.

Of the Veins.

The other set of tubes—the veins—were considered as less active, being principally employed in bringing the red part of the blood back, after it had lost its most salutary parts, or performed those offices, whatever they are, for which it was sent out.

This act of carrying back the red blood was not considered as the only office of the veins; many of their beginnings were not only supposed to arise from the terminations of arteries, but were also supposed to arise from most, if not all, the surfaces of the body, both internal and external, making so many inlets into the general system, bringing in matter into the common mass of fluids for the support of the whole; and also to bring back many of the parts which were by the arteries secreted from the blood for the different purposes of life, such as the synovia and lubricating fluids of all kinds; which fluids having answered their different purposes, and having become unfit for any further use in the machine, were obliged to be brought back again into the circulation, to be thrown out of the constitution by the arteries.

So far the use of the veins was considered; but part of their supposed power of absorbing they were deprived of, from the discovery of that part of the absorbing system called lacteals, which were found to absorb the chyle. Though by this discovery the veins of the mesentery were deprived of the supposed use of absorbing the chyle or nourishment, yet even then they were supposed to absorb matter from the cavity of the intestines for the secretion of the bile.

Of the Absorbents.

The other part of this system, called lymphatics, though long known, was not in the least suspected of performing the operation of absorption, but they were still supposed to be continuations of the extreme ends of arteries, which were not large enough to carry red blood, only carrying the serum or lymph; but from their similarity to the lacteals, which now were known to be absorbents, it became at last plain and evident to common sense that they must also absorb.

Before this idea was started, the general opinion of the vascular system ran thus:—The arteries carried the blood for the growth, nourishment, secretions, &c., in the machine:—the veins returned the red blood, as also absorbed from every surface of the body:—the lymphatics returned the lymph of the blood, which came along the arteries; and the lacteals were sharers in the intestines by absorbing part of the chyle. But from some experiments I made to ascertain whether the veins of the mesentery absorbed or not, it was proved that they had not the power of absorption[1].

Of the Heart.

The heart is an organ or machine that is not common to all animals, many being entirely without such organ: how far it accompanies the brain I have not yet discovered, but I suspect that a distinct brain and a distinct heart go together. Where there are both brain and heart, they keep an exact analogy; so much so as to teach from the one what the other is like, which would make us suspect that they are always to be found [together] in the same animal.

The situation of the heart is generally near the upper, or what may be called the anterior part of the body of the animal; but this is not universally so, only in those animals where nature would keep pretty

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[1] Subsequent experiments have invalidated that conclusion.

near to general rules, such as in the general structure of the more perfect animals down to fish; but beyond them it is not clear where the heart may be placed in an unknown animal, and it is even differently situated in the same genus; for example, the situation of the heart in the shell-snail [*Helix*] [1] is not the same with that of the black snail or slug [*Limax*] [2].

The external form [of the heart] varies in different animals, and that difference most commonly corresponds with the shape of the part in which it lies. In the human, for example, it is flattened on the anterior surface, answering to the flat breast [3]; [it is] more so in the seal, otter, &c.; but this does not always take place in flat chests. In general it is a cone [4] more or less flattened on one or two sides, but principally on one; this flatness generally constitutes the great difference in shape in any one class; the shape of each class differing from each other according to the different purposes of each, or number of parts of which it is composed.

A heart is essentially simple in its construction; the use of each part is perfectly understood and of course [that of] the whole. It is a muscle or muscles making the parietes of cavities which have no fixed point of action, excepting an imaginary one, viz. the centre of the cavity, to which the whole body of the muscle moves in its action, by which means the cavities are lessened.

The heart is, in general, divisible into a number of cavities, the greatest number consisting of four, the fewest consisting of one only. The first [or most complex] division constitutes [causes] a distinct and double motion of the blood; the second, a mixed motion; the third, a single circulation, but attended with a very singular circumstance in its passage, viz. in gills; and the fourth, not a circulation, but an undulation.

Of the First Division of Hearts.—Here the body called heart is formed of two distinct hearts, each having its auricle and ventricle, with distinct veins opening into the auricle, and each ventricle its artery passing out.

Although the above division is true, from whence it might be conjectured that there was no communication between the two circulations, yet nature has connected them by means of the viscus, viz. the veins corresponding with the arteries of the right side, shift sides and go to the left, and *vice versâ* of the left side. The valves are similar in all.

This division comprehends the most perfect animals, which have a double circulation, one through the lungs, the other through the whole body, and for that purpose are furnished with a double heart. The two auricles and two ventricles make up the four cavities by which these animals are distinguished, whence they may be called *Tetracoilia*.

[1] [Hunt. Prep. No. 882.]
[2] [Ib. No. 883.]
[3] [Ib. No. 929.]
[4] [Ib. No. 928.]

Of the Second Division of Hearts.—This is a mixture between the first and third, by which means it is more imperfect and much less distinct than either. This heart consists of two distinct cavities, and of two others which are not so perfectly distinct, and which act only as one cavity. The two distinct cavities are the auricles; the ventricles communicate so freely with one another, that they are to be considered as only one cavity; therefore these [animals with the above structure of heart] may be called *Tricoilia*. There the blood from the lungs, and that which has gone through the other parts of the body, mix together, instead of being separated, as in the more perfect animals; so that some of the last sort is thrown back through the body again without passing previously through the lungs, and some of the first sort is pushed a second and perhaps a third time through the lungs, without being first employed in the general circulation.

The veins of each auricle enter distinctly, as in the first division of hearts; but the arteries arising from this mixture of ventricles are more complicated. They are not exactly the same as to anatomical structure in all of this class, although much the same as to use, producing nearly the same effect in all of them. To give an idea of this, we shall describe them in the turtle (*Chelone Mydas*), which will sufficiently explain their use in all the others [1].

From the compound ventricle of the heart in the *Tricoilia* arise three arteries, two of which are anterior, the third posterior. Of the anterior, that to the left hand, which is also the largest, is the pulmonary artery, going to the lungs nearly, as in Man; that to the right hand is the left aorta: and the single posterior artery is the right aorta, which alone gives off the carotids and subclavians. These two aortas make a curvature downwards, descend together along the back, and when got to about the middle of the cavity of the animal, unite into one trunk. This union is similar in some degree to the union of the two arteries coming from the gills in fish.

This description is taken from the turtle, and although it may not exactly agree with all of the above class, as the frog, &c., yet it will in the essentials. Here the lungs and the whole body are evidently supplied from portions of the same mass of blood. But no use appears for the two aortas in this division, and they seem so very superfluous, that one might be tempted to suspect they were only provided to lay the foundation of an analogy with the animals of the immediately inferior class, the Pneumobranchiata [2], and of the class below them, the Fish [3].

For in fish that have only one auricle and one ventricle, the single

[1] [Hunt. Preps. Nos. 918, 919, 920.] [2] [Ib. Nos. 912–917.]
[3] [Ib. Nos. 904–911.]

artery which the heart sends off is immediately distributed to the two sets of gills; from these the blood passes out in two trunks, one on each side, which after running a little way join into one vessel, as the two aortas do in the turtle; which now runs on as an artery to supply the rest of the body with blood, without having first entered a heart, or what is called the left auricle and ventricle.

Thus the difference between the two classes is considerable; but nature, always proceeding by the nicest gradations, has formed two animals which partake so much of the structure of the two classes, that they gently lead us on from the one to the other. The first of these, as being nearest to the amphibious tribe, are the animals now before us[1], which, indeed, form the next link in the chain that we are acquainted with, as will be easily seen by comparing them together. The present have but one auricle[2] and one ventricle, sending off one artery, which is common to the gills and lungs, and which might be called 'pneumobranchial.'

Here is a falling off from the Amphibia of an auricle, and in some measure of a ventricle, notwithstanding which, the effect of the heart upon the blood is nearly the same.

The artery passes out of the heart, sending off the pulmonary arteries, which are ramified upon the lungs as usual, and then divides into two branches, which are analogous to the two arteries in the turtle; but as these animals (*Amphiuma* and *Menopoma*) are a degree nearer fish, these arteries are each again subdivided into two, which afterwards wind round those singular parts—in some measure similar to the gills of fish—with which they are furnished. Having made this circuit, the subdivided vessels again unite so far as to form only two trunks, and these two presently join into one in the same manner as we have remarked in turtle and fish.

The other animal—the siren—completes the gradation by being one remove nearer to fish: in this the subdivision is not into two branches only, as in that above described, but the whole aorta divides and subdivides into infinite ramifications, similar to the artery in the gills of fish, while the lungs are supplied in the same manner as those of the preceding animal and of the Amphibia.

Thus the gradation is formed from perfect lungs, first to perfect lungs and imperfect gills, then to perfect lungs and perfect gills, till at last we have no lungs, but simply perfect gills, as in the fish.

The animals of this class have but a single circulation, and of course

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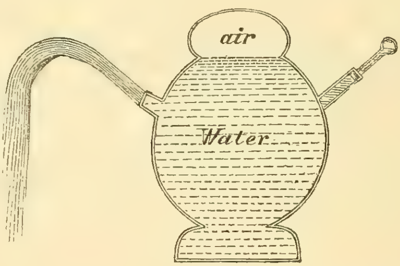
1 [*Amphiuma didactylum*, Cuv., and *Menopoma Alleghaniense*, Harlan.]

2 [I found this auricle divided by a complete septum in the *Siren lacertina*.—Trans. Zoological Society, vol. i. p. 213; 'Animal Economy,' p .396, note. Prep. Mus. Coll. Chir. No. 913A.]

are furnished only with two cavities to the heart, viz. an auricle and ventricle, similar to and answering the same purposes with the right half of the heart in the most perfect animals[1]. To this order belong all the fish with gills; therefore these may be called *Dicoilia.* The last order comprehends the animals whose hearts have only one cavity, as is the case in the insect[2], therefore they may be called *Monocoilia.*

Of the Uses of Arteries.

The arteries may be said to have three uses. The first and most simple is, the conducting, as canals, the blood to all the different parts of the body. For this purpose they are acted upon by the heart, which is the cause of the motion of the blood (the veins would seem to be, in themselves, passive). But as this motion is by jerks and not by a uniform regular motion, the arteries are made elastic, which [makes them] serve, in some measure, as a reservoir; while their contractile force continues the stream, although not with the same velocity. This is something like [or upon the same principle as] the air-fountains, or jets, which might be made to imitate the elastic force of the arteries, such as this figure; but as there is a continued elastic canal, which may



be looked upon as a succession of elastic bodies, every one having some effect, it may be reasonably supposed that in the smallest arteries there is very little pulsation, which we find to be the case; so that the jerking force of the heart is gradually spent, or fades into the continued [force]. All this is simply mechanical.

The second use of the arteries is the first purpose answered by this motion of the blood, or the disposing of it. This depends on the living and sensitive principles with which the arteries are endowed, joined with a power of voluntary motion in arteries independently of the general will of the animal, and according to the impression made, joined with the disposition or feelings of the arteries at the time. Then such

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[1] [Hunt. Preps. Nos. 904–911.] [2] [Ib. No. 979.]

and such actions are brought about, and such and such effects produced, which can only be in the small arteries. When the blood is good and genuine, the sensations of the arteries, or the dispositions for sensation, are agreeable; then the offices of the arteries are carried on suitably to the intentions of nature. It is then that they dispose of the blood to the best advantage, increasing the growth of the whole, supplying any losses, keeping up a due succession [of organic particles], &c.

The third use of the arteries, is that of secretion in all its various forms. This must in some measure arise from stimuli which are of this or that kind; and from the arteries of particular parts being susceptible of such and such stimuli. Without both uniting or concurring, secretion could not take place.

These actions depend upon a principle similar to that which is the cause of the second use of arteries.

The most perfect proofs of the actions of the arteries in propelling the blood forwards, is in an aneurismal sac. If the artery above the sac be compressed so as to prevent the blood flowing, the sac which was just before pulsating and turgid shall immediately become flaccid and wholly empty. Nothing could produce this but the action of the arteries beyond the sac, and principally the smaller arteries[1].

Of the Continuation of Life in an Artery after the Animal is said to be killed.

I injected the uterus of a cow that had been separated from the body of the cow above twenty-four hours; and I found next day that it had contracted very much, and that the vessels had also contracted; for the great trunks were more turgid than when injected, so that the injection had been squeezed back again[2]. This also shows that the small vessels have a greater or a longer power of contraction than the larger have.

Origins of Arteries.

The force of the blood's motion in an artery is stronger the nearer to the heart, therefore it is reasonable to think that the situation of the heart in the body is such as [that it should be nearest the parts which] require the briskest circulation. But the difference in the circulation, if there was nothing to retard it, would be too great for the difference in the parts, as there are similar parts near and at a

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1 [In the production of this phenomenon Hunter assigns no share to the emptying of the veins by the diastole of the heart and expansion of the chest.]

2 [May not this be the effect of elasticity in consequence of the parts having been put into hot water while being injected? I have seen that happen.—Wm. Clift.]

great distance. To keep up a circulation sufficient for the part, and no more, nature has varied the angle of the origin of arteries accordingly. Thus we find that near the heart the arteries arise by obtuse angles; some of them reflected; which become more and more so, till they arise by very sharp angles. The more remarkable instances of this are in the intercostal arteries; because there is not another set of arteries in the body whose origins are so much the same, whose offices are so much the same, whose distances from their origin to the place of use [distribution], and whose uses are so much the same. Therefore, if there be any difference in the angles at the origin of the arteries at equal distances from the heart, it must be with regard to the distances of their insertion [termination?] from the heart. And there is such a difference. Even the arteries that arise from the intercostals are much more obtuse at the beginning of the intercostals than at the termination.

The reason that it is not so evident in all the arteries, is that there are not two arteries on one side of the body that take the same course, go the same distance, and are to do the same thing; for some parts require a stronger circulation than others, which will make a difference in the origin of two arteries, supposing they go the same length and the same course.

We see the same thing in the secondary arteries, such as the subclavian. It sends its branches off near its origin by much more obtuse angles than it does further on; for in this artery all the branches are to do nearly the same things, and are to go nearly the same length, which was what we observed in the intercostal and lumbar arteries.

The vasa vasorum seem to come from a neighbouring artery, not from the artery that it supplied. This we see in dissecting them. But to see if some of these should arise from the artery itself, I injected a carotid artery out of the body, but none of the vasa vasorum were injected.

The nearer you come to an artery in the living body, the less the pulsation is either felt or seen; and when dissected bare, the motion of the blood is not to be seen or felt with the finger in the least[1] [viz. in Dr. Hunter's servant's sister's external carotid].

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[1] [That the arteries are dilated during the pulse, Flourens saw by enclosing the abdominal aorta, in a rabbit and in a dog, in a ring made of very fine watch-spring, the ends being merely in contact: at every stroke of the heart these ends were divaricated, but in a very slight degree. Weitbrecht (De Circul. Sang. Cogit. Physiol.) was the first who saw that the principal cause of the pulse was the displacement of the artery by the jerking power of the heart.]

We find, on the contrary, that the more they are covered, especially with solid bodies, the more the pulsation is felt; viz. in tumours covering the carotid, &c.

There is certainly a pulsation in veins[1]; for, when we bleed a person in the hand or foot, we evidently see a strong jet; much more in some than in others, and much more than in the bend of the arm. The query is, does this arise from the immediate stroke of the heart, or is it by the lateral pressure occasioned by the swell of the arteries? To ascertain this the better, it is necessary to observe several things. [One of these is, that] the veins on the back of the hand are superficial and not surrounded with vascular parts: but still it may arise from the impulse given to the blood in the smaller arteries occasioning their lateral swell, and that this acceleration given to the blood's motion in the smaller veins is communicated to those on the back of the hand. But I think I have seen the difference in the projection so great, as hardly to arise from that cause alone; and if this were the whole cause we should have it in some degree in every vein; for every vein is in some degree surrounded, and of course in some degree affected by the swell of the arteries of the part; but we certainly do not observe it in so great a degree in the bend of the arm.

The veins in the spleen of a dog do not anastomose. I tied up one of the veins going to one end of the spleen; that end immediately became turgid and of a dark red, while the other end remained flaccid and of the former colour.

The spleen is the reddest part of any in the animals of those classes which have red blood; so that there is more red blood in the spleen than in any other part.

Of Food.

Food may be divided into two sorts; viz. that which is wholly dissolvable in the stomach, and that which only yields its juice.

The first is the most profitable, and includes all animal food, excepting cuticle, hair, nails, horns, &c.; [it also includes] roots without the skin, all fruits without the skin, and all seeds without their skin or husks.

The second includes all the other parts of vegetables that have not been mentioned above, such as the wood and leaves. Many yield so little

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[1] [Flourens observed in the venous trunks of frogs alternating movements of contraction and dilatation: Müller is inclined to attribute this to the influx of the lymph propelled by the lymphatic hearts; but Flourens thinks the veins he observed to beat were too remote from the lymphatic hearts to be so influenced. Jones has observed a pulsation in the veins of the bat's ear.]

as to have lost apparently nothing [by digestion], only having yielded [some small proportion in] a solution. This food yields nourishment chiefly by expression; and least so in those animals that have a stomach of but one cavity. In order that more of this juice might be expressed in some animals, nature has furnished four stomachs [or cavities]. But even this does not dissolve it entirely; for we find the dung of such animals a good deal of the colour of the food; for example, a cow's dung shall be green when she lives on grass.

The instinctive principle of food in animals is a curious fact: a stork which swallows birds, mice, rats, frogs, &c., will not swallow a toad. He takes it up in his bill, and after nibbling it, as if to kill it, he lets it fall; and this he will do several times, and at last leaves it. The sea-gull, which will eat the same food as the stork, will not touch a toad. Animals do not seem to distinguish food accurately by the eye; they seem to be only directed to it, and give a kind of general guess; but they are obliged to have recourse, for further particulars, to the other senses. Quadrupeds commonly, if not always, have recourse to the nose; therefore they seldom take into their mouth what is not fit for them to eat: but the bird seems to have but little smell; and therefore the nostrils are at some distance from the end of the bill[1]; and when they are directed to food, [the fitness of which] they are not certain of, they take it into the mouth, and, if it be unfit for food, they throw it out again[2].

We do not distinguish things at once by the senses: the simple sensation does not in all cases inform the mind with the true idea of the thing represented: the mind is often obliged to inquire how it is that a hollow of any particular shape, and a round of the same shape (a concave and a convex surface), give the same shades and will appear concave or convex according as the mind is most susceptible of the idea, or has been accustomed most to conceive it to be. But a little reasoning upon the collateral circumstances attending the sensation will determine the simple impression in the mind to be what it really is. It is often extremely puzzling in paintings or drawings to make out what the painter means; for, if the corresponding relative parts are not attended to, the reasoning faculty has not its materials or data to direct it, so as to be able to draw its inference, or make its conclusions. This must be always the case with things, the knowledge of which is ac-

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1 [Except in *Apteryx*, where, from the terminal position of the nostrils, the smell would seem to be a much used and important sense.]

2 [This I have observed in the ostrich, where a piece of leather was repeatedly picked up, tested by frequent nips with the mandibles, and then rejected.]

quired; of which things our knowledge always becomes more perfect by habit.

The food of almost all young animals is principally of an animal nature. In the sucking kind, whether of carnivorous or granivorous parents, the young have the milk, which is a compound of animal substance and sugar. In birds, animal substances are principally the food for the young granivorous, which live, at first, principally on insects, worms, &c.

Are there any granivorous animals that feed only at night, as there are many carnivorous? I should suspect not: because there are no herbs found at night but are to be found in the day; but this is not the case with the animals [which serve for food]. However, it is possible that there may be some animals which live only on the flowers that are open at night.

Of the Teeth.

As the stomach is the digesting organ of the food of animals,—is in common a containing part in the form of a bag or bags,—and as it is generally placed on the inside of the animal, there must be an external communication to that cavity: and as the food is either passive, as vegetables, or active in contradiction to that process, as most animal food, there must be a mode of collecting, catching, adapting, and conveying that food to, and through that communication to the stomach.

Various are the means of doing all these operations; and this variety of modes arises, from the nature of the food which the animal lives upon, [from] different modes of digestion (as the difference between a ruminant and a horse), also [from] a great variety of circumstances attending that food, the nature of which when caught may be often similar. The first of which [circumstances] I shall reckon fluidity, as honey, the juices of plants, such as what many insects live upon, &c. Secondly, [the food] being alive, therefore [involving] a mode of catching and killing, which requires a greater extension of parts [concerned in those actions], and then to separate parts from the whole. Thirdly, collecting parts of growing vegetables. All of which [circumstances require] parts formed and adapted for such purposes. Most of these operations are performed by the mouth, or beginning of this communication in some animals; and in many others by the mouth with its other apparatus, as teeth; but it has often still more exterior assistance, as hands, claws, feet, &c.

These operations may be divided into three, although all the three are not necessary in every animal. The catching and collecting is the first; the fitting some food for digestion, and adapting most for deglutition, is the second; and the conveyance of that so collected and adapted into the stomach, is the third.

The mouth, which is the principal actor in these operations, is, in many, formed alone for these operations; and these formations are according to the nature of the food, and circumstances attending that food, viz. its natural situation; as honey, which requires an apparatus to get to it, which is a mode of many of the winged insects; [in other instances requiring a particular form of] the lips, as in some fish, *e.g.*, the sturgeon; [or of] the tongue, as in the ant-bear, &c.

The parts of an animal immediately preparatory to deglutition and digestion are divided, in those that live on solids, into two kinds, viz. bills or beaks, and teeth: to which, probably, may be added a third, viz. those [parts] of insects which are exterior to the mouth. A mixed kind may, also, probably be added, viz. those that may be classed either with the teeth or with the bill, such as the dividers of some reptiles, as the snail, leech, &c. The bills are exterior, and are placed on, or surrounding, the mouth of the animal: they are of the same shape with the mouth, making a case for it; and as the mouth is made up of two parts opposing one another, commonly called upper and lower jaw, the bill is also composed of two parts, or a pair.

That class of parts of an animal preparatory to deglutition and digestion, called teeth, is so extensive, and of such various forms and uses, that it is uncertain in some cases what parts ought to be classed among the teeth and what not; and in those where they are evidently for this purpose, it becomes difficult to class them either according to their various uses or their forms.

In some animals there are teeth for deglutition and others for digestion; for example, there are the nippers [*mandibulæ et maxillæ*] of a crab or lobster, while those for digestion are in the stomach: and where teeth are not necessary for [preparing the food for] digestion, they are wholly for deglutition, as the grinders [carnassial or flesh-cutting teeth] in a lion, cat, &c.

The teeth are always placed between what may be called the brim or margin of the mouth, and the first intestine; viz. [in the] mouth, œsophagus or stomach. Those subservient to deglutition are always placed in the mouth, viz. between the margin of the mouth and the œsophagus, having at the mouth a border of soft parts surrounding them, called lips, which is much more in some animals than in others, and which is the beginning of the mouth.

The mouth is the most frequent situation of the teeth, at least in those animals we are most acquainted with, viz. quadrupeds, amphibia and fish. In some reptiles they are placed in the œsophagus, as in the

—— and —— [1]; and in some animals they are placed in the stomach, as in the water-insect or crab, &c.

Those in the mouth may be divided into two situations:—First, all those forming two rows in each jaw (*i. e.* one row in the right, and another in the left jaw), and opposed by similar rows in the opposite jaws; secondly, where the teeth are placed on other parts, as the tongue. The first situation admits of divisions, as where those rows are single, as in the quadruped and amphibia; [or where] they are double, triple, &c. rows, as in many fish, where the four rows mentioned are composed of a vast number of rows of teeth.

They may be classed according to their uses, which I shall at present reckon four, viz. holders or retainers, which may be called killers, dividers, crackers, and grinders; the two last of which may be thought the same.

The dividers are always more external than the grinders. Some dividers are always external, others are some way within, some more, as in the—(nereis?); some less, as in the snail. Some of the grinders are as far forward as the dividers will allow them, as in those which have mouths filled with both kinds, as in most of the more perfect animals; but in many those grinders are placed in the stomach, but then those have their dividers wholly external [as in the lobster]. Teeth are commonly fixed in or upon some bone, which [bones] are commonly the jaws of the animal: but this is not always the case; in the lamprey there is no jaw-bone.

Some teeth grow to a given size, and then become stationary, as in most animals, viz. the human, &c., some of which teeth last through life; others, of the same animal, are thrown off at given ages, called shedding of the teeth, and are again supplied by others, which last through life. In some other animals there is a regular succession of teeth, by the falling off or destruction of the teeth, and new ones continually growing and gradually coming into use; the new teeth being always a proportional size longer than the old; the jaws of which [animals] follow the same course, so that there is a regular succession of jaw and teeth growing: this is the case in many fish, as in all the ray-kind. In others there is a succession of young teeth growing at the basis of the old, or rather within the old, so that the old (tooth) drops out like a conical case, and the young one is uncovered [Crocodile]. Probably the young tooth grows on the same pulp, so that these teeth never

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[1] [Quære, Myxine, Nereis? The term Reptiles is commonly applied by Mr. Hunter to the *Vermes* of Linnæus; whilst the *Reptilia* of the modern zoologists he usually denominates Amphibia or Tricoilia.]

draw towards a point at the base, but always keep open or conical, yet do not always continue to grow, as the tusks.

Some teeth are wholly composed of bony substance, which is a mixture of two different substances, viz. a mixture of animal substance and calcareous earth: such are those of the ray-kind, alligator; as also some peculiar teeth of some animals whose teeth in general are not so simple, such as the elephant's tusk, boar's tusk, &c. The teeth of many animals are composed of the two above-mentioned substances, but in one degree in a different manner, viz. one part being composed of bony substance, the other of calcareous earth alone [called 'enamel']. The teeth composed of bone and enamel belong to man, the cat, the hare, the horse, ruminating animals, &c.

The bony part of both genera are formed upon and by a pulpy substance; therefore the whole of the first genus [with teeth wholly composed of bony substance] is formed by this pulp, but only the bony part of the second; the enamel is formed by an opposite pulp, which makes it complicated. How far horny substance may be so shaped as to deserve the name of teeth, I do not yet know[1].

Teeth continually growing I have divided into two species: first, the 'dentes scalprarii;' and second, the 'tusks.' The first belongs to the hares, &c., the second to the boar-tribe; as also to the narwhal, and probably many more.

Reasons for a vacant space between the Cutters and Grinders.

Most animals have a vast length of mouth from the symphysis of the chin to the posterior grinder or the root of the coronoid process. The incisors or cutters must be placed at the fore part, where the opening into the mouth is, because there the food must enter and be divided from what is to remain out of the mouth. The mouth being properly filled with food, it is then thrown back, or up, to near the centre of motion of the jaw where the grinders are placed. Now, in all long-jawed animals there is a space in which teeth of any kind of shape can be of no use; they could not, from the position, separate the internal food from the external, and the space is too far forward for grinders to be of any use. This vacant place is shorter in proportion as the jaws are shorter, [and more so] in some animals than in others; and in some there is very

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[1] [The substance resembling bone in the proportions of earth and gelatine, is divided into 'dentine' and 'cement,' which latter Hunter had recognized as 'a second kind of bone.' There is a minute proportion of gelatine in enamel, and this substance covers the crown of the teeth of the alligator. Since Hunter wrote the above, the *Ornithorhynchus* has afforded the reply to his remark on horny teeth.]

seldom any vacuity at all. The gradation from the least to the greatest is evident. The human subject is the least of any[1]; then the monkey, mocock, sagouin, bear, lion, dog, and horse. The question is, why have some animals longer jaws than others? This great length of jaw may be on purpose to increase [add to] the length of neck in eating such food as is near the ground, as grass, &c.

Animals that are truly carnivorous, such as lions, wolves, dogs, foxes, &c., have their teeth pointed with one or more points, and smaller points surrounding the base of these points. They have the enamel surrounding the crown, and the bony part entirely in the middle of the tooth; the fang terminates in a point, and has no enamel. The fang is long, and the body of the tooth is short, at least that part which is sunk in the gum and socket.

Animals that are eaters of vegetables, such as elephants, horses, cows, sheep, goats, deer of all kinds, also all of the 'Scalpris Dentata' kind [*Rodentia*, or rat and rabbit kind], have the grinders terminating in a surface equal to the thickness of the body of the tooth. The enamel in all of them runs through the whole tooth from end to end, in a kind of veins very irregularly, and the fang or fangs do not terminate in a point, and are very short from the body of the tooth, which makes the body of the tooth longer than in those of others; at least that part which is sunk in the gum and bony socket [before it divides into the fangs] makes the largest portion of the body of the tooth. Those animals of the mixed feeding kind, such as the human, monkey, sagouin, &c., have the teeth, with regard to the body, the fangs, and the enamel, similar to the carnivorous. The teeth, in the gradual change from the carnivorous [type] to the most herbivorous [one], begin [the change] first at the posterior grinder, and become more of the herbivorous forwards, till they are lost entirely in the fore teeth[2].

Of the Formation of the Teeth of the Horse.

The bony part first begins on a substance similar in consistence to that of the human, but of very considerable length, and four or five in number, in the grinders.

This [complex dentinal pulp] lengthens as the teeth lengthen, so that the tips of them [divisions of the pulp-substance] are always near

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[1] [No existing species has the tooth-series so compactly in contact as man: a few extinct animals (*Dichodon*, *Anoplotherium*) resembled him in this respect.

[2] [The teeth, especially of the lower jaw, of the hog illustrates the meaning of this statement.]

the grinding surfaces of the tooth. The external membrane of the tooth [matrix] does not adhere to it at first, but forms the enamel on the outside of the bony parts covering the jellies [divisions of dentinal pulp]. As there are more jellies than one to each grinder, there are inequalities on the external surface, or narrow notches, into which these pass in folds of the external membrane, like the pia mater, so as to fill or lie close to all the external bony surfaces.

These bony processes, which we might term sheaths, unite at their edges to one another; so that there are cavities between them through their whole length, running parallel to the others which contain the jellies.

These cavities or canals are filled up with gelatinous substances, which pass into them from the general covering at the base [of the matrix] and terminate at the bottom of the tooth in a ragged white end between it and the basis of the other jellies touching them; for, at first, these interstitial cavities are pervious at both ends [top and bottom], and continue so till the tooth is almost completely formed.

These interstitial jellies form the enamel which runs the whole length of the tooth, along its centre in a very irregular manner, answering to the form of the irregular cavities formed by the union of the bony parts. The doublings or folds of the internal part of the external covering which we mentioned as pressed in laterally, have the same white termination at bottom which we took notice of in the above described. When the tooth is pretty far advanced, the bottom or apices of these interstitial cavities close up, and then may be said to form but one cavity, all the jellies uniting into one: afterwards, two or three fangs arise, as in the human grinders.

The external membrane, with its folds, forms the external enamel; and, when that is formed, it then forms a thin bony covering [cement] to the whole, which fills up the niches and makes the external surface more equal at this time; at this time, too, it unites with these bony coverings, beginning first at the bases and proceeding to the root or fang, as the tooth advances through the gum. The interstitial jellies, also, form the interstitial enamel; and, when that is completed, they line the whole with a bony matter [cæmentum], or, in other words, fill up the whole interstices with a bony matter. When the interstitial jellies begin to form this bony matter, they also adhere to it as the external membrane did first, beginning at the bases; which adhesion goes to the bottom as the external adhesion did. The interstitial jelly becomes more and more membranous as it fills up this cavity. By the time the tooth is just ready to cut the gum, these interstitial cavities are entirely filled up, so that the tooth is one solid mass of two different substances[1].

Relation of Teeth to Food.

The teeth of animals are not always answerable to the food they eat. The horse and cow feed upon the same food; a snail also lives upon the same food, and the tooth of a snail is very different from the teeth of either [cow or horse]. Nor do the teeth of animals correspond with their stomachs. Animals that have nearly the same stomachs have very different kinds of teeth.

The formation of the mouth, so far as respects the teeth, seems to be adapted to the catching or laying hold of the food. Thus, those animals that live upon animal food have the shortest mouths, and their teeth are regularly set; but those that live on vegetables have their heads long, much longer than is requisite for the number of teeth. Therefore the jaws are prolonged to allow the catching teeth to be removed farther from the grinders.

Most land animals have the upper jaw the longer, overshooting the under; but this is not so much the case in fishes. In most of these the lower jaw is the longer. The anterior parts of the mouth of a fish is not [rarely] made for dividing[2].

Of Eating.

Those animals that have no upper teeth I should imagine eat more of the roots of grass than others, because they do not cut the grass, but pull it, which brings it out by the roots in some measure. All animals that chew their food, have lips, which are to confine the food: but those that swallow it without mastication have none.

Motion of Lower Jaw.—In carnivorous animals there is not that grinding motion of the lower jaw, in eating, that is to be found in others: the articulation will not allow it, nor will the canine teeth; but still they have a little; and the motion of the two condyles of the jaw, in that case, is not forward, but from side to side, in a groove: this is quite contrary in other sorts of animals; for in them one condyle is always the centre of motion, and the other condyle with the symphysis of the jaw moves; but in the former the symphysis is fixed and the two condyles move.

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[1] [A study of the Hunterian preparations, Nos. 333–349, 373–375, will much assist in the comprehension of the above description, and will give the grounds of the interpolated terms which seemed needful for the understanding of the text.]

[2] [The beaks of the parrot-fishes (*Scarus*) and globe-fishes (*Diodon*, *Tetrodon*) are exceptions.]

Of Drinking.

All carnivorous animals, as far as I know, drink by lapping up the liquor with their tongues; *e. g.* dogs, foxes, ferrets, &c. The reason, perhaps, may be because they have very short lips and very little use of them in taking their food of any kind; for, as they are made to catch animals, they must make, at once, use of their teeth; and lips, in that case, would be in the way of the teeth.

All herbivorous animals, as far as I know, such as cows, horses, sheep, &c., suck up the liquid in the same manner as the human kind; but the goat sometimes sucks and sometimes laps. These animals make use of their lips to catch and conduct their food between their teeth.

I believe that the mouths of herbivorous and granivorous animals have many more [mucous follicles], or are much more glandular, than [those of] other animals.

Of the Œsophagus.

Those animals that chew their food, such as most granivorous, have a smaller œsophagus than such as only mash or squeeze it, such as the carnivorous, and still smaller those that swallow it whole, such as fishes and many birds. According to the teeth is, in some degree, the size of the œsophagus.

Of the Stomach.

The apparatus necessary for the operation of digestion is as simple as anything we can well conceive. It only requires a bag or cavity fit to contain the substance to be digested, joined with the power of furnishing the fluid capable of digesting or animalizing the said substance. In such a light, it is only to be considered as a gland with a cavity. But it was necessary that there should be some part added to furnish this bag with materials to be digested; for which purpose there are, in some, arms; in others, both arms and teeth, &c.

Besides the simplicity of the apparatus for the operation of digesting, there is another apparatus added to fulfil the intention, which is the system for absorbing the animalized parts for the nourishment of the same bag; and added to this power of secretion and absorption, is the power of throwing out of the bag the indigestible parts, acting as a kind of excretory duct*.

From this account, nothing can be more simple; however, it completes a whole animal, and nothing more can be necessary for the support of such an animal; but when we come to such stomachs as have parts superadded for other purposes than the above, then we find that

* Nothing more is necessary to complete an animal, than the power of continuing the species, which power is superadded to this bag in many.

this same apparatus for digestion has also parts superadded for the purposes of digesting; so that the parts preparatory and subservient to digestion, become more complicated, and indeed so much so, that there is hardly any system in an animal more complicated in itself; and when we consider the varieties of these complications which take place in the various animals, they appear to be almost without end.

It is these complications and varieties that we mean to consider, and reduce, as far as they will admit, to their several classes.

The parts subservient to digestion in the complicated animals bear a great relation to the other properties of the animal*.

In classing the organs of digestion in the complicated animals, many parts are to be considered which appear from a slight view of the subject to be only secondary, and therefore might be thought necessary to be considered apart: but we shall find that many of these parts have peculiarities, and these are adapted to the peculiar food and peculiar mode of getting it, and not at all belonging to simple digestion in particular.

These superadded parts, which have their mechanism adapted to the way of life with respect to digestion, are the powers of mastication,—in some, reservoirs,—the varieties of stomachs,—whether or not a cæcum, and of what kind,—and colon; so that in classing the organs of digestion, we must consider teeth, stomachs, cæcums, and colon.

The stomach varies less than either teeth, cæcum, or colon. One can easily see a reason why the teeth should vary according to the mode of procuring the food, and according to the food; and one can easily conceive why the stomach need not vary much, because it can only be considered as a bag; but why so much dependence is to be had upon the cæcum and colon, is not so easily conceived. In classing stomachs, it might be thought proper to take in all these relative parts; but that method would breed confusion. Therefore I shall class all the different stomachs with their varieties; and in classing the other parts they must be referred to their respective stomachs. This will appear most natural when we consider that there are many stomachs that have no relative parts, which I shall naturally begin with, as the first class.

Our first class is the simple stomach with one opening, which I call *Regurgitators*[1].

* Animals in general might be tolerably well classed by these organs, most being reducible to a few general classes, which again admit of many subdivisions.

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[1] [As in the *Hydra*, or fresh-water polype, and the *Actinia*; the other classes of stomachs, as they rise in the scale of complexity, may be studied in the Hunterian Preparations, Nos. 409 to 590 inclusive.—Physiological Catalogue, vol. i. 4to, pp. 114–181.]

It is hard to determine what is the true shape of the stomach while in the living body, as it takes on different shapes in proportion to the fullness of it and different pressures; but it will always have a tendency towards that which it takes when inflated. Stomachs cannot be divided according to the food which animals eat, because the shape in many, whose food is very different, is nearly the same.

In all quadrupeds, as far as I know, the stomach is shorter and thicker than in the human, and does not become so gradually smaller towards the pylorus.

Of Digestion.

Digestion is a process that is similar to no other process in nature: if it was in any way similar to the natural changes that animal substances alone, vegetable substances alone, or where both substances mixed, undergo when left to themselves—I say, if it were so, then—digestion would be equally good in all animals and in all people. But it is so unlike these natural changes, that in all bad digestions these natural changes are in a small degree allowed to take place. Digestion depends upon a principle that belongs to the containing, and not to the contained, parts.

The [power of the] containing [organ] may, and does depend on the disposition of the body and mind, not so much on the constitution or strength of the body; for many weak constitutions have vast power of digestion, and others the reverse. Its effects are immediate on dead substances; almost as quick as the effects of an acid on an alkali. Its power depends upon life; for, as soon as life is gone, even in the most healthy, this power is lost, excepting what may be going on [at the time of death], which continues for a little time. It depends on a living principle in itself; but that which is to be digested must be dead, or have lost this living principle, or it cannot be dissolved.

Like all other fermentations, it cannot act upon any living principle, either animal or vegetable; that principle must be first lost before any change can be produced. If it was possible for an animal to live in the stomach of another animal, supposing digestion not to be going on in that stomach, it would then live while digestion was going on; for that animal would not be in the least dissolved, because the living principle in the animal would prevent or counteract the digestive quality of the stomach. If this was not the case, then we might readily suppose that even though the animal life was not immediately affected by the digestive power, yet at last it might be destroyed by the external and extreme parts of the animal being digested, and so the animal be obliged to die, like a person with a mortification. But that a living animal will not be so dissolved is every day proved by worms, maggots of flies[1], living in the stomachs of many animals; and if it was a power that could act upon a part that had the living principle, as well as an acid can, then the stomach itself would certainly be dissolved.

If one could conceive a man to put his hand into the stomach of a lion and hold it there without hindering the digestive powers, the hand would not in the least be digested; and if the hand of a dead man was put in at the same time, whether separated or not from the body, that hand would be digested, while the other would not[2].

All carnivorous animals, as far as I know, both quadrupeds and birds, throw up from their stomachs any substance that is not fit for digestion which they swallow with their food: the eagle, hawk, owl, &c., when they swallow hair or feathers and bone along with the meat, afterwards throw it up; because these substances not being dissolved with the meat, they are left in the stomach, and by its action they are coiled up into the form of a ball and then thrown up. The bones and hair of a mouse coiled up, with dirt or sandy substance, is thrown up from the stomach of an owl.

It is the same with the dog; for if a dog happens to swallow any of these substances, they throw them up in the same manner. I have seen a dog eat hay which was sticking to the meat, and afterwards throw it up matted together.

The blood which a leech sucks is not digested in the belly, but lies pretty pure and but little coagulated; and is absorbed into the substance of the animal like the nourishment of a vegetable, and is there assimilated, and the excrementitious parts are sweated through the skin. Leeches are of that class which have no anus[3]. They are fond of blood, but a very little kills them. If they have not sucked a great deal they will live a long time with it in them, and spew it out a little at a time; but they seldom recover. The blood they suck is both venal and arterial, because when we open them we find it is mixed, and of

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[1] [The stomach bott, or larva of the *Œstrus Equi*, is the most familiar instance of this kind.]

[2] [The *Hydra viridis* occasionally performs such an experiment for us, swallowing one of its own arms along with its prey; but, while this is dissolved, the living part of itself is disgorged uninjured and resumes its functions. Nay, sometimes one individual is swallowed entire along with a worm which a stronger polype may have seized; in this case the worm is digested, but the weaker polype soon disengages itself from the stomach of its conqueror, apparently unaffected by the digestive solvent. As Hunter's matured conclusions on the digestive process were published by him (Animal Economy, pp. 81–121), his speculations in MS. on its 'fermentative nature,' &c., are not here given; having been, apparently, abandoned by him.]

[3] [The medicinal leech has a rectum and vent opening above the hinder sucker.]

two colours, but principally arterial. It does not coagulate so firmly as when exposed to the air. This blood is preserved from putrefaction by the animal's powers for months; however, it becomes more black than what it is at first. By adding fresh water to them, it will often make them throw up their blood after it has been in for months: this I have seen.

That the juices of the stomach have the power of coagulating many substances, is clearly seen in the stomachs of some fishes that eat crabs, lobsters, craw-fish, &c.; for if you open a grig a little while after it has swallowed a craw-fish, you will find that the shell is turned red, as if it had been boiled or steeped in spirit of wine[1].

Many animals which feed upon green vegetables have those vegetables ferment and they burst. The seat of fermentation is very different in different classes of animals. In ruminating animals it is in the first cavity of the stomach, where a great quantity is taken in much more than they can ruminate, so as to get it to the digestive stomach before fermentation commences. Accordingly the air which is let loose is more than the stomach can contain, and it bursts. As such animals have the power of regurgitation, one would conceive they might throw up the air, but they do not.

For such complaints they pierce the abdomen and the 'first' bag with a trochar; but I conceive that if a hollow tube was introduced into the stomach, the air might be evacuated that way.

The other situation of rupture from the fermentation of green vegetables is the colon in horses; the stomach has the power of preventing this process, as also the small intestines where its passage is pretty quick.

Of the Intestines.

As the intestinal canal in brutes is more detached than in the human subject, and only adheres by the mesentery, it is almost impossible to say exactly what is the true situation of these parts, they being so subject to vary in their situation.

The reason why the duodenum is seen in all its length in brutes is, because neither the cæcum nor colon adheres [to the abdominal walls], as in the human subject; it is only that part of the mesentery that is seen on the right which attaches the ileum to the colon and cæcum that covers the duodenum, as the cæcum adheres lower down than the transverse part of the duodenum.

The small intestines of herbivorous animals are generally smaller and longer, their great intestines much larger and longer, than those of the

[1] [This rather exemplifies the acid quality of the gastric juice.]

carnivorous animals. Why there should be this difference in the first [small intestines] is not so easily accounted for; but perhaps the last [difference] is to allow of a longer continuance of absorption, as the food is less similar [to the animal it is to become part of] in the herbivorous than in the carnivorous [species]; and therefore it has a less tendency to putrefaction, as we find to be the case; for in all herbivorous animals we have their excrements less putrid than in the carnivorous ones. Those animals that have but a short cæcum or none, and which generally have but a short and small colon, have their excrements always thin.

What is the use of the villous coat of the intestine? It cannot be for absorption, as many of the surfaces of cavities that absorb copiously are entirely smooth. Is it for sensation?

In many animals it was necessary to have the last part of the intestines [colon is meant] larger than the others, that the food might be deprived of its thinner parts; and, perhaps, the lymphatics are not so large here as in other parts. The colon is largest in those animals whose food has the least nourishment in it; which food does not go wholly through the stomachic process [is not completely digested in the stomach], and which food undergoes but little change, consequently such animals, *e. g.* the horse, &c., have a much larger quantity of excrements: therefore the contents must stay longer [in the colon] than in the other intestines.

However this may be, it is certain that the fæces have not such a quick passage, therefore must become putrid; which was the cause perhaps of a valve at the termination of the ileum, that these putrid contents might not regurgitate. If we understand the use of a valve, we shall understand the use of a cæcum. This seems to be no more than the valvular insertion of the ileum[1]; for if it had been a sudden swell in the gut, there could have been no valve. The cæcum is longer in some animals than in others. In all animals that I know, the length is in proportion to the width, except in the human subject, where it is shorter; and in man it is more fixed, which may be one reason of its proportions.

A new-born child has no air in its stomach or guts; of which one reason is, that they do not take down anything by the mouth; nor is there any putrefaction, or anything analogous to it in the guts.

In the human subject there is a difference between the intestines of the fœtus and the adult. In the fœtus there are no 'valvulæ conniventes;' but the intestines are longer in proportion. Thus in

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[1] [Hunt. Prep. No. 724.]

a child a week old, 1 foot 4 inches in length, the small intestines measured 13 feet 2 inches, which is 9·25 times the length of the child; and the great intestines measured 1 foot 8 inches: so that the whole length of the intestines was 15 feet, being ten times the length of the child.

In another child, 1 foot 9 inches long, the small intestines were 13 feet, and the great 1 foot 8 inches, which makes the whole 7·99 times the length of the child.

In a third child, the intestinal canal was 7·28 times the length of the body.

These three had [each] their 'appendix cæci' 2 inches long.

In a child that was 3 feet 1 inch long, the small intestines were 20 feet 1 inch long, the large intestines 3 feet; being 7·12 times the length of the body.

In a man that was 5 feet 7 inches long, the small intestines were 25 feet 9 inches, the large intestines 5 feet 2 inches, the whole 30 feet 11 inches; which comes to 5·53 times the length of the body.

In another man of 5 feet [in stature], the small intestines were 23 feet, the large 4 feet, the whole being 27 feet; which is 5·4 times the length of the body[1].

Of Air in the Bowels.

Much air in the stomach and bowels is a sure sign that these bowels are weak. It first shows a bad digestion, the food running too much into the putrefactive kind; and it shows that they are not able to expel it when let loose; for air is much more difficult to expel than common fæces. This we see to be the case in the guts out of the body, for it requires closer squeezing to expel the air than the other contents. It will regurgitate if the intestine is not held tight; so that if the guts are not able to contract upon the fæces so as to shut up the passage entirely, it will be impossible to expel the air. In people that die in full health, we find little air in the intestines; and what there is, is found in the ileum, which is the weakest intestine.

Of Excrements.

The excrements would seem to be made up of the parts of our food that do not animalize, of the parts that are changed in the digestive process but not animalized, of the parts that are not digestible, of the parts that the lacteals have not taken up, that are or may be animalized,

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[1] [In comparing the relative length of intestinal canal to body in the human and lower animals, the length from vertex to vent should be the measure taken for the body in man; whereas the lower limbs are included, as in the instance in the text.]

and of the juices of the body; which juices may be either thrown out of the body as useless, or be such parts as were intended to stimulate the guts, as the bile.

The thickening change which takes place in the excrements as they pass through the alimentary canal, would appear to arise from rest; for, when into the colon, the motion of the excrements cannot be so quick as in the small intestines; and when the parts are in a sound state, we never find anything like thick excrements, even in the ileum, or even like thin excrement; for there is a very material difference between the contents of the ileum and the contents of the colon: but that this does not arise from any peculiar property in the colon, but from rest, appears from the dissection of Miss Limm! [Where is this? (asks Wm. Clift.)]

Of the Absorbents.

It would appear from experiments that the absorbents do absorb after all communication is cut off between them and the brain and circulation*. This is no more than that contracting or acting power which parts have that are not dependent on the will, which is far more lasting than those powers where the will has any influence. I observed in a dog, whose carotid artery I tied, that the lymphatics were likewise tied, and that by next morning the lymphatics were very turgid with a clear lymph. I collected it in a tea-spoon, and found that it coagulated with heat. It is most likely that every cavity of the body has absorbents, excepting the cavity of the stomach; for, from all the observations that ever I could make, I never could find any there. I collected some lymph from a lymphatic on the loins of a new-killed dog, and observed that it had a good deal of the coagulable lymph in it, but the serum that was expressed by the coagulation of the lymph did not coagulate by heat. How is this? for the lymph in cavities has none of the coagulable lymph in it. Do the lymphatics communicate with the arteries?

The absorbents seem to be capable of taking in some things and not others; or they reject some things and receive others; and, in one state, they can reject, while in another they receive the same thing; for instance, the small-pox [virus] is not received by the skin, but by an ulcer. The lymphatics would seem to be affected by stimuli, for where there cannot be the least reason to suppose an absorption, they are affected, and the glands also.

* *Vide* Book of Experiments on Absorption. [Where is that Book?—W. Clift.]

Mr. Williams, who pricked his finger with a clean needle, had the glands in his arm-pit swell, and had small rigors; almost immediately upon receiving the wound, a line of pain ran up the whole arm to the glands.

The lymphatic glands being only in the *Tetracoilia*, and the absorbents being much more neat in their construction, having a number of valves, in that class, would show that the fluid absorbed is to be more perfect than in other classes. The lymphatics appear to be entirely influenced by the living principle[1], not by the sensitive. We know of no power which the will or the mind has over the absorbents.

The absorption is certainly not begun according to the principle of attraction by capillary tubes. In the first place, it would require rigid tubes for such effect[2], which we cannot suppose to be the case, as so vast a number of such tubes upon the skin would be liable to a thousand accidents which would render them unfit for their purposes. Secondly, if absorption was left to such a uniform acting principle, there would be no choice: every substance would be absorbed equally, for a capillary tube cannot refuse any fluid. Things that were insalutary would be as readily absorbed as things that are salutary, which we find not to be the case; for we find some things absorbed with difficulty, till a disease is produced similar to the kind of substance to be absorbed, such as the venereal matter; for it is seldom absorbed excepting from a venereal sore.

It is more in concord with the general principles of the animal machine, to suppose that none of its effects are produced from any mechanical principle whatever; and that every effect is produced from an action in the part; which action is produced by a stimulus upon the part which acts, or upon some other part with which this part sympathizes, so as to take up the whole action.

Major Hughes had a *fistula in ano*, for which he had been cut; but it never entirely healed from the bottom; however, it sometimes healed at the mouth, which produced an accumulation of matter at the bottom, which produced inflammation, ulceration, &c.; but what was most remarkable, was a swelling of some of the glands of the groin of the same side.

[*Vide* my own case, viz.] I had the point of a pair of scissors run in for a little way into my hip, just behind the great trochanter, and a gland of the groin became sore the next day, viz. when the inflamma-

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1 [The term is here used in the sense of the 'Automatic life' of Bichat, which is a compound of 'Organic Sensibility and Contractility.']

2 [This structure is not required for that passage of fluids through animal membranes termed 'endosmose' and 'exosmose,' or imbibition.]

tion attacked the wound. If this was from absorption, then the lymphatics behind the great trochanter pass forward to the glands of the groin; if by sympathy, it is most probable that it is from their taking the same course.

Dropsies of the legs are always observed to be most swelled towards the evening, and least so in the morning. This is generally attributed to the legs being the most depending part, and that all the water naturally falls to these, and by lying in bed it as naturally returns back again, and diffuses itself over the whole body. This may often be the case; but I am persuaded that this is not always the case, and that the swelling through the day arises from extravasation taking place in the day, and that the subsiding of the swelling in the legs through the night, is from absorption.

This was certainly the case with my own leg; for, first, the bandage was so tight round the calf, as not easily to allow the water to pass up into the thigh; and, if it had soaked past in the night, it would have been obliged to stagnate a little above this bandage before it could get to the ankle, as it would be in some measure retarded by the bandage; but nothing of this kind happened.

If this be the case, then the extravasation must be owing to the small vessels in the weakened part not being able to sustain the column of blood while the body is erect, or nearly so; but when laid in a horizontal position, the vessels are then able to support the force of the circulation; and then the lymphatics absorb this water already thrown out in the day.

Of Lymphatic Glands.

Lymphatic glands become larger and larger towards the thoracic duct. If lymphatic glands were guards upon the absorption, then there would be no occasion for internal lymphatic glands; or, if guards upon internal absorption as well as external absorption, then they would produce worse disease in themselves than that which they were intended to prevent. I should imagine the glands are cellular, because the lymphatic ones are filled when we blow into their substance. Now if the substance of the gland was only ramifications, I should expect the veins and arteries would fill as soon as the lymphatics. But this is not a sufficient argument; because whether the lymphatics open into cells, or are only branched, they make the largest part of the gland, and are much wider than either arteries or veins. As to any use that we know the lymphatic glands to be of, it seems to me immaterial whether they are cellular or are divisions of the lymphatics; for both would seem to answer the same purpose.

From the black mucus often hawked up in the morning, after being accumulated through the whole night, it was supposed that it was secreted by the dark-coloured lymphatic glands that lay about the trachea; but it certainly is not, these being truly lymphatic glands.

Of the Natural Lubricating Fluids.

All cavities have a fluid of some kind for the more easy motion of their sides [and contents] upon one another. Some have it in large quantity, as the ventricles of the brain, pericardium, joints, &c.; some have it in small quantity, as the thorax, abdomen, tunica vaginalis testis, and common cellular membrane. Where it is in large quantity we can judge of its nature, but where it is in very small quantity it is almost impossible to judge. One way of judging is by comparing one with the other in the diseased state of both; or in that disease which produces an increased quantity [of the natural fluid]. When there is an increased quantity of fluid in the ventricles of the brain (excepting from inflammation), the fluid is the same as when it is only natural in quantity. The same [may be said] of the pericardium and of the joints.

From thence it is reasonable to suppose that when there is an increased quantity in the thorax, abdomen, tunica vaginalis testis, and cellular membrane, this fluid is similar to the natural [fluid].

Our internal canals are passages for our secretions, as also for extraneous matters, as fæces, air, &c., in which cases they may be said to be both passive and active, although [they are] probably never entirely passive. They are most passive in the ureters and urethra, but principally the last, as also in the trachea; and are most active in the intestines. But even where they would appear to be least active, as in the trachea and urethra, yet they are active so far as concerns their own matter or themselves. Thus the urethra acts to press its secretions, or any extraneous matter forwards, and I am persuaded the trachea has the same power.

It is more easy to conceive how a flexible canal, such as an intestine or urethra, may have this power, when we know that they can act so as to shut up the canal. Their actions are all directed one way, beginning at one end; but, as we cannot suppose that the trachea can shut up its passage so closely as to compress its contents forwards, and if they do come forwards and even upwards, mostly in the human subject, then there must be some other mode of action to effect this. That the mucus of the trachea is gradually conveyed up is a fact, and the only thing wanting is the mode in which it is done[1]. I conceive that

[1] [The action of the vibratile cilia of the tracheal mucous membrane would have been a welcome spectacle to Hunter, if it could have been shown to him in a good modern microscope: it would have realized his pre-conception 'of a constant action of the mucous surface, tending to convey the mucus upwards.']

the inside of the trachea is in constant action, and that that action is always directing the substance attached to it in its own direction. This might be attempted to be illustrated by the effect produced on a hair when rubbed between the fingers and thumb; for, although the motion in the finger and thumb does not direct the hair to take any course, yet it moves in one direction. This arises from the surface of the hair. But the same thing would happen if the fingers had the same kind of surface with the hair, and the hair the same with the fingers. It might be supposed that the air passing out might give this direction [to the mucus in the trachea]; but I should hardly conceive that sufficient; for the air must also pass the contrary way, which, if equal in current, would keep it stationary. However, we may observe that the air passes out with greater velocity than it passes in.

Organs of Secretion.

Secretion cannot be called fermentation, nor can it be called filtration, but it is a separation of such parts of the blood as the particular glands are fitted for; and such as are either obnoxious to the constitution, or, as when combined, or united again, have properties according to the parts separated.

In all our secretions there is a great deal of that substance called mucus: indeed mucus would seem to be the basis of most. The other ingredients are the distinguishing marks by which means they are called 'this' or 'that.' The urine, sweat, perspiration, and the tears, would seem to contradict this opinion; but there is mucus in all of them. The formation of mucus seems to be the natural animal change into which she forms herself when she intends throwing part of herself out of the constitution, either for waste or for other purposes, such as digestion and motion of the parts already formed: so that most of the secretions that are to answer some particular purpose, as the bile, semen, &c., have the particular property mixed with mucus.

In many of our secretions, there is mixed with the mucus something which gives us the idea of bitter. The bile has this constantly, but less in some animals than others; and less at one time than another. The wax of the ear has it. The mucus on the tongue in a fever, or after a debauch, has it. I should be apt to suspect that this principle is of a vegetable nature, similar to the bitters of that kingdom.

Of the Liver [*loose note*].

From the liver being but one long lobe in snakes[1], &c., it would appear that the vast division in the liver of the dog[2], &c., is not for

[1] [Hunt. Prep. No. 802.]

[2] [Ib. No. 806 (Cat).]

motion; as nothing has so much of the bending motion as a snake. However, where the liver is divided into many lobes, they will admit of a sliding motion on one another.

In a dead woman, sitting on a chair, the lower angle of the right lobe of the liver came as low as the angle between the colon and ileum; thence it ran obliquely upward to the angle of the cartilage with the seventh rib on the left side. The gall-bladder was perpendicular, three inches below the angle of the cartilage with the seventh rib on the right side. The lower end of the spleen was just two inches below the cartilages of the ninth and tenth ribs, which is just opposite the navel. The stomach was below the navel and on its left side. On laying her on her back, all these parts went three inches higher. Every part seemed to be in its natural situation and size, only the stomach was lower than usual.

Notes and Queries on Bile.

What is bile? It mixes more readily with spirit of wine than with water; but still very readily with water. Bile is a secretion, not a fermentation. It is a decomposition of the parts of the blood made by the vessels of the liver; or, in other words, a straining off of such parts as, when united again, make a combination called bile.

Has not bile more vegetable juice in it than any other secretion excepting the milk[1]? It is bitter; gives a tinge to water, alcohol, &c.

When the bile is stopped from going into the intestines, then follows a costiveness. This shows that the bile acts as a stimulant to the intestines, and is a kind of natural purge. As this is really the case, we cannot suppose that the bile goes through the stomachic fermentation; therefore it is not digested. Again, we cannot suppose that the bile assists in digestion or the stomachic fermentation, as it never enters the stomach in a natural state, and, when it does, it produces a contrary effect, viz. a nausea. This shows that digestion is carried on in the stomach alone, and shows why the bile should not enter the stomach, as its natural effects might be destroyed by being obliged to undergo a change in its nature*.

It appears very evident that the bile is only a natural purge, for it undergoes no change in its passage through the intestinal canal. The contents of the duodenum are white, with a faint yellow tinge; but the lower they go the yellower they become. This is owing to the greater

* Does soap go through the stomachic fermentation, as it is found to kill worms?

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[1] [Here Hunter is thinking of the 'sugar' of milk.]

dilution of the bile in the duodenum ; and, as the contents are absorbed, the bile becomes less and less diluted, so that it becomes more and more apparent; and, as it becomes less diluted, it, of course, acts more as a stimulant to the last intestines.

These circumstances are plainly seen in some animals whose bile is of a bright or high green colour, and which have a large quantity ; for in them the contents of the upper part of the intestines are only a little tinged, but those of the lower part are of a strong colour. This is still better seen in those animals that have fasted long, where the bile is but little diluted. Bile is, I should suppose, bitter in insects, but not in the oyster, muscle, lobster, &c. This last circumstance is a strong proof that the bile is not digested and absorbed; for in very hungry animals we should not expect to see anything in the state of bile in the intestines, if the bile went through the stomachic digestion.

If the bile is intended as a natural purge, and as many animals regurgitate the excrementitious part of their food, the question suggests itself, Is bile necessary for regurgitation, and have those animals bile? We can regurgitate without bile, and many birds regurgitate part of their indigestible food without bile. Therefore probably all those animals which do regurgitate their excrementitious parts [*Medusæ, Actiniæ*] have nothing analogous to liver and bile, but only those animals that have intestines.

We often find gall-stones transparent. Is this the salts of the bile crystallized?

On the Gall-bladder.

Some animals have gall-bladders and some have them not. Those that have a gall-bladder, must have part of the bile passing into the gall-bladder, and the other part into the gut at all times. Those that have no gall-bladder, must have the bile always passing into the gut. This difference arises from two circumstances; the first is, that the bile which is constantly used must be thin; and bile that is only used at certain times is required to be thick.

Now it would appear that some animals require bile equally at all times; therefore they have a constant supply of bile, which is thin. There are other animals which seem to require bile, but more at one time than at another; the bile which they are constantly in want of is thin, whereas the other is thick.

Now if this were not the case, Nature could easily have made it otherwise; for instance, if that bile which is always wanted by right should be thick, then Nature could have placed a bladder in the middle of the duct, which would have served as a reservoir, where it might have become thick, and yet in a continual flow. But where there was a continual flow, she wanted thin bile. Again, if she wanted thick bile where it continued to flow, in those animals which have the gall-bladder she needed not to have made a hepatic duct, but only a hepato-cystic duct; which would have poured it always into the gall-bladder, which again would have poured out nearly the same quantity by the cystic at all times; but then it would have been thick bile. We see something like this in fowls; but then they have a hepatic duct which constantly pours in thin bile.

Supposing that we wanted thin bile at all times, both that which is wanted at certain times and that which is wanted constantly; then it would have only been the not making lymphatics to come from [and absorb the watery part of the bile in] the gall-bladder.

Now the thing to be considered is, why the constant bile should be thin and the other [intermittent bile] thick?

It is disputed whether the gall-bladder secretes bile or not. This perhaps can only be determined by diseases of this part. When Lord Bristol was opened, there was found in the cystic duct a large gall-stone which appeared to fill tightly the duct, so that no bile could pass. The gall-bladder was very much contracted although not diseased, and its contents were a pellucid slimy mucus, not in the least tinged nor bitter to the taste. *Vide* Dissections, vol. p. [? Wm. Clift.]

As some animals have gall-bladders and others none, it may be asked, What is the use of the gall-bladder? Is it to keep bile for particular times, or is it to keep a constant flow of bile; supposing the liver to secrete only at particular times? However this be, the last does not seem to be so probable as the first.

Of the Pancreas.

The pancreatic juice would seem to be absorbed. The cuttle-fish would show this. [How? asks Wm. Clift[1].]

Of the Kidneys.

The bodies called kidneys are glands intended for a secretion of a fluid, which in common language is called 'urine.' Their use is immediately to carry out of the circulation such parts as are useless and

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[1] [Hunt. Prep. No. 775: "Pancreas of the Cuttle-fish." It shows the numerous follicles, communicating together so as to form small elongated groups or lobes, whose common ducts open not directly into the intestine, but into the hepatic ducts, extending along them from the lower part of the liver to the spiral laminated duodenal cavity. *Vide* Physiological Catalogue, 4to, 1833, p. 229. Swammerdam observes, of the spiral cæcum of the Cuttle-fish,—"It contains a matter like the pancreatic juice of other fishes."—Bibl. Naturæ, fol. p. 889.]

obnoxious, becoming the common-sewer of the constitution; but those parts must be carried off by a change being performed in them, constituting a secretion.

These bodies probably do not exist in every animal; at least they are not to be found in every one, most of the inferior orders of animals having visibly no such bodies, which is one mark of their inferiority; although it is probable that in them other common parts may serve the same purpose, or perform the same action; for instance, it is probable that the intestines of such perform the same office.

As these bodies, in those animals which possess them, are to perform an office peculiar to themselves, they are distinct parts from all others in the body.

They are, from Fish upwards, in pairs; but below Fish, as in the cuttle-fish, snail, &c., there appears to be only one. Their situation in the body varies in different animals. From Fish upwards they may be said to be placed within the belly of the animal, near to the back; but below them, in the inferior orders, where both their number and situation are not the same with those where they are evident, it becomes uncertain whether such bodies, whose use is not immediately seen or obvious, are the kidneys or not; nor is it so determined where they may be placed; as, for example, in the cuttle-fish the kidney is in the anterior part of the belly, in the snail by the lungs[1].

In some orders of animals they are very circumscribed bodies, being enclosed in a proper membrane or capsule, as in the most perfect orders, and in some degree so in Amphibia; but in Fowl they are more obscure, being placed in the hollows of the pelvis; while in Fish they are still less detached, lying all along the sulcus made by the spine, and are closely attached to the parts behind, not having there any particular capsule.

In some animals the kidney is a very oblong body, extending in length for a considerable way, and very narrow, as in some Fish[2], while in other animals it is almost globular, as in the leopard[3].

In some the external surface is smooth and regular, as in the human subject; in others covered with large branches of veins ramifying on it, as in the lion tribe, &c. In others, again, the whole mass is lobulated into several parts, and very irregular on its surface.

The consistence of the kidney is in general a pretty solid substance, but most so in the most perfect animal, appearing to become less and less so to the inferior orders, for in fish they are of a very tender substance, and still more so in the snail.

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[1] [Hunt. Prep. No. 1176.] [2] [Ib. No. 1185.] [3] [Ib. No. 1202.]

In the inferior orders of animals the kidneys are pretty much of the same uniform substance through the whole[1]; but in the quadruped they appear, when cut into, to be formed of two different substances, one called the 'cortical,' from its being exterior, the other the 'tubular[2].'

The cortical substance has its distinguishing appearances from its vessels running in all directions, having no particular direction of fibres, and also having the cryptæ interspersed everywhere through its substance. The other substance, or tubular, is placed towards the centre of the kidney; when cut in one direction it appears to be made up of parts or fibres passing pretty parallel to one another towards the centre, and when torn in that direction it splits into numberless fibrous parts. This substance begins insensibly in the surrounding secretory part, and passing inwards, they of course converge and terminate at once, forming one side of a cavity, called the 'pelvis.'

As the kidneys have another action of their blood-vessels superadded to that of support, similar to every other secreting body, and which is to dispose of some of the blood in secretion besides the nourishment to the part itself, they are therefore endowed with supernumerary blood-vessels for such purposes, and are of course extremely vascular when compared to many other parts of the body.

These vessels in Fish and upwards arise from the great artery, or aorta, as that artery passes along the back-bone. In Fish this great artery is giving off the arteries to the kidneys through the whole course of the kidneys, therefore there are a vast number of small arteries going to those bodies. In Amphibia and Fowl the kidneys are more collected and of course their arteries are less numerous, and larger in proportion; but in the still more perfect animals [mammals], where the kidneys are more circumscribed bodies, there we have in common only one artery to each kidney, which is of a very considerable size.

In those kidneys where the arteries go into them in small branches, as in fish, &c., there is not that necessity for their very quick ramifications, for being originally small, they come soon to their ultimate arteries; but in the others, where the artery goes into the kidney by one trunk, and therefore is large, it is obliged to ramify very quickly, in order to form the ultimate arteries.

As the arteries of the kidneys in Fish come to them in innumerable small branches, and as the motion of the blood in those animals is slow and languid, the arteries therefore appear to terminate in their ultimate branches, as in other glands. But in the more perfect animals, especially the quadruped,—where the artery goes into the kidney in one short

[1] [Hunt. Prep. 1186.]

[2] [Ib. No. 1218.]

large trunk, where the motion of the blood is very rapid, and where they are obliged to terminate soon in the ultimate branches, which continue the rapidity of the blood's motion in them,—there we find that the arteries necessary for the performance of the secretion of urine, take on a little twist, convolution, or spiral turn, called 'crypta,' intended for the retardment of the blood's motion, to allow of secretion; but the termination of every artery in the kidney has not these cryptæ; and as they are confined to the external parts of the kidney, they give a peculiar appearance to this part distinguishable from the rest, whence the substance of the kidney in this order of animals is divided into the two kinds above mentioned, viz. the cortical and the tubular.

The veins of the kidney in common follow the arteries: however, there are exceptions to this rule. In the lion kind, cat kind[1], as also in the hyæna[2], we find that perhaps one half of the veins get on the external surface, and are either strongly attached to, or pass in a doubling of the capsule of the kidney, and then pass along like the veins of the pia mater, afterwards joining the trunks from the inside just as they pass out.

The excretory ducts of kidneys in general may be reckoned intermixed everywhere with the secretory, forming a regular ramification of branches and trunks. The ultimate branches are of two kinds; first, where the excretory, or what may be called the first order of ducts, arise in every part of the kidney, then unite and form trunks, which may be called the second order, and these unite and form the third, and so on, forming at last the ultimate trunk, called the ureter, as in Fish[3], Amphibia[4], and Fowl[5]. The second is where the secretory and excretory are pretty distinct, not intermixed as in the first, the secretory being the most external, the excretory the most internal[6]; and where the excretory do not at all unite into larger and larger branches, forming in the end one common trunk, as in the first; but where they all open into a cavity or reservoir, called pelvis, which is placed in a pretty deep sulcus in the inner edge of the kidney[7].

The mode of opening into this reservoir admits of some variety, but may be divided first into two species. The first species is where the excretory ducts, after forming the second and third order, open into the pelvis on a concave surface, as in the horse, ass, &c.[8]; the second is where they form a projection or projections, called mamma or mammilla, which are projected into this cavity, and the excretory ducts open on

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[1] [Hunt. Preps. Nos. 1200–1205.]
[2] [Ib. No. 1206.]
[3] [Ib. No. 1186.]
[4] [Ib. No. 1192.]
[5] [Ib. No. 1196.]
[6] [Ib. No. 1222.]
[7] [Ib. No. 1218.]
[8] [Ib. Nos. 1208–1216.]

the point or edge of such[1]. In some there is only one mammilla, and one infundibulum, as in the lion tribe[2]; in others there are a great many mammillæ and infundibula, as in the bonassus[3].

Loose 'Notes and Queries' on the Kidney.

The kidneys of all viviparous animals are much higher than those of the viviparous 'ex ovo,' or of the oviparous animals. Why so, is perhaps not so easily accounted for, excepting it be to allow of more room for the growth of the uterus. The kidneys in the two last are in what may be called the pelvis, and the urethra, in them, enter the common passage of the oviduct and rectum.

Why do the *ductus urinarii* of the kidneys enter the pelvis on a convex surface? This may perhaps be to prevent a regurgitation back into the blood; as we see in the liver from a stone in the ducts[4].

Of Parts whose uses are not known.

The *capsula renis* is a wrong name for those [suprarenal] bodies, as they are not attached to the kidneys in all animals: in the lizard they are placed between the testicle and epididymis.

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1 [Hunt. Preps. Nos. 1219, 1242.]
2 [Ib. No. 1219.]
3 [Ib. No. 1258.]

4 [This query could only relate to the higher animals, to which, as Hunter has just shown, the 'convex surface' or mammilla is peculiar. In all oviparous Vertebrata the 'ductus urinarii' are directly continuous with the ureter, of which they are indeed ramifications; and, among mammalia, the solipeds and some other odd-toed hoofed beasts (*Tapir*, *Rhinoceros*) have the tubuli terminating on a concave surface, and can be injected from the pelvis. Nevertheless the structure of the mammillæ in other mammals seems intended to prevent regurgitation. Does the disposition of the renal ducts in the Ovipara depend on the absence of constriction or resistance at the end of the ureter, which is so placed as to allow of a ready and constant discharge of the urinary secretion? Does the absence of a urinary bladder permit the superabundance of earthy salts which characterizes the urine in these classes, there being here no intermediate cavity or receptacle in which that matter can accumulate to form a calculus? It is evidently at variance with the structure of the bird that it should be encumbered with an accumulated excretion, and consequently it is in the ostrich and similar birds without the powers of flight, that the convenience of a urinary receptacle is met with. This is, however, less perfectly adapted to that end than in mammals. In the cold-blooded Ovipara a greater or less proportion of the allantois remains. The accumulation of fluid contents in this cavity can be of little physical consequence to animals which never raise their bodies from the earth; and are in general characterized by the sluggishness of their motions. The bladder, however, appears in these to serve other purposes than that of a urinary receptacle; if it ever be filled with mere urine at all. (Tie up the ureters in a frog or tortoise, and see if the urinary bladder becomes empty, also what kind of urine accumulates in the constricted duct. Is it from the possibility of regurgitation into the tubuli, that a horse stands still, and allows nothing to interfere with the evacuation of the bladder in staling?)]

The spleen seems not to have any immediate connexion with life. It can only be classed with the extreme parts of the body; for animals can go on as well, to all appearance, without it, as those that have it. The common use assigned to it seems to have no foundation, as it is of so very trifling a size in some animals. In the lizard it is not half the size of one of the testicles. In fowls it is in the middle of the body, and therefore it cannot be formed for a balance to the liver.

Of the Oil or Fat.

The oil or fat of an animal increases with age; but, even in the young animal it would appear that it was necessary that there should be some substance as a substitute for fat; for in those places where oil is most to be found in the adult, there we find another substance in the young subject. It is not an easy thing to say what this substance is; it is more or less oily. In the new-born child it is hardly dissolvable with heat, and hardly inflammable; and is of a greyish white. It is not universal through the interstices of parts, as in the adult. As the animal advances this substance is changed more and more for oil, and becomes more and more dissolvable by heat, more and more inflammable, and also more and more diffused, and of a yellow colour; for instance, the tallow of an ox, the oil in the [human] feet.

Of the Brain[1] *and Nerves.*

As the nerves are large in proportion to the size of the brain in the more imperfect animals, and as these animals have life in a greater degree than the more perfect in proportion to the size of brain, we may reasonably suppose that the nerves are the cause of simple life.

It seems evident that the brain has such power over the nerves as is, in some degree, mechanical; for the nearer to the brain the nerves [are, they] seem to have more influence, or are stronger in their action; and, therefore, the medulla is sent down the spine, and the organs of sense are placed in the head; and in animals whose nose is some way from the brain, the olfactory nerves run a considerable way pulpy, as in the crocodile[2].

Injuries of the brain seldom or ever affect immediately the actions of the heart and arteries. The pulse is regular and soft, but often full. The brain would seem to have two powers; the one, *sensation*, or a consciousness of the body, by which means it regulates the motions depending upon it; *the other*, where it supplies simple life; for we all know that an animal may live after such injury has been done to the brain so as to take off all sensation, as we see in many fits.

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[1] [For Hunter's views of the leading modifications of the brain in the animal series, see p. 29.]

[2] [Hunt. Prep. No. 1315.]

The voluntary energy of the brain is not in proportion to its size, and seems to bear no kind of proportion [thereto]. The power of the brain to stimulate a nerve to action, and the effect or power of that action of the nerve upon a muscle, is as strong in the insect as in the human subject; therefore, whatever properties size of brain may have in an animal, they are not, in the brain, employed upon the body, but employed about its own actions, as in a greater effort of the mind, and a greater scope of reasoning. Nor does a large brain require larger nerves to make the impression of sense[1]; I believe, rather less.

A nerve is a sensitive organ, but has no business with the mind; for if a nerve has informed the mind of anything, that nerve may be totally lost, and yet the remembrance of the thing will continue; so that the nerve has done its whole business in communicating its impressions to the mind. We are too apt to take effects for causes; and it is natural for us to do so, because the effect comes first, makes the first impression, and in most cases it is not necessary to look out for a cause. Impressions or sensations are effects:—the causes of the impressions are external bodies.

Nerves have nothing to do with muscular motion [in itself]; a muscle has all the powers of action without nerves; but muscles must have a stimulus.

Muscles are divided into two kinds, one having a constant stimulus, and which never tire, [others having the stimulus of the will, and which do tire.] There is also a mixed kind; where muscles act by the natural stimulus and do not tire, and where they are exerted beyond that stimulus by the will, when they soon tire. Therefore it is the stimulus of the will that tires.

It is impossible for the mind to form just ideas of causes and modes of action where neither cause nor mode of action is known; nor, probably, within the reach of human sagacity. These reflections are immediately applicable to the causes and actions of an animal body. We see the body move. We go further; we see the parts that have within themselves motion, which is the immediate cause of the motion of the whole; and we see how that motion can be excited. But all this does not give us the first cause of motion in those parts, nor does it explain the mode of action of the parts themselves.

The only thing, probably, left for us to do, is to observe, as much as possible, all the visible causes of motion in those parts of motion; which of course will give us all the visible effects: carrying these researches into every class of animals; seeing how far they vary, so as to be able

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[1] [The organs of sense are generally inversely to the brain as to size: compare the eyes and internal ears of fishes with those of birds and mammals.]

to demonstrate by one, that which in others may not be essential [as a cause of motion], only fitted for particular purposes; for the essential must be the same in all. A muscle is the power that acts, or has the power of action in itself.

Our sensations are our regulators respecting good or evil; but that is only respecting our bodies. A considerable degree of heat, above 100°, *e. g.*, so as to give pain, will coagulate the juices. A pinch that will give pain, will also do mischief to the part.

Is sensation a sympathy of the brain with the part injured?

The senses inform the mind, the mind in return informs the senses. Sight gives us light and shade; feeling gives us the cause, viz. inequality; and habit of the two makes the last [touch to teach the eye] unnecessary. When habit of another kind takes place, then light and shade do not give the idea of inequality. A slab of variegated marble does not give the idea of an irregular surface.

When a disagreeable sensation takes place joined with a disagreeable reflection, or is accompanied with some disagreeable circumstance, then it becomes too much for the human frame; for instance, the sawing off a man's leg, or, what is still worse, cutting the human flesh with a rough instrument; it becomes horrible.

Pains of the inflammatory kind arise from the nerves of the parts being affected by the parts themselves being affected; but pains of the nervous kind arise from the nerves themselves being affected, without the parts being affected that these nerves go to.

The senses are not always regularly proportioned in every person; some sense being acute, while another is obtuse; and the contrary in another person.

The intellect or understanding has an immediate connexion with the senses, and the senses with the intellect. But we find that the different senses have not always the same share of this connexion; some sense being capable of informing the intellect much more than another, and the intellect using that sense upon every occasion, and neglecting the others. To explain this by example: we find that some people cannot pay attention to what they hear, but search for objects of sight, in order to be informed by the eyes; these retain what they do see, and can readily reason from it, while they lose the connexion [between the subjects addressed to the eye and the ear], and forget the half of what they hear. On the other hand, one shall not be able to pay attention to what is before his eyes; and, if nothing be said, nothing is noticed; but he will listen to trifles while grand objects are before his eyes.

If it were possible to have more senses than what we have, it is very probable we might lose by the gain. We are certainly not capable of managing more variety of sensations than what we have at present, and many are not capable of managing those. Take away a sense from some, they would be tolerably sensible.

Of Sensibility arising from involuntary actions of Voluntary Parts.

Although muscular action arising from the disposition of the muscle itself, called spasm, is almost always attended with sensation more or less, often [with] pain, and that very violent, yet this is not universally the case; for I saw a gentleman who had involuntary contractions of the orbicularis muscle of the left eye, and the muscles of the angle of the mouth of the same side, and there was no pain, not even a sensation in the muscle that acted. This is the first case of the kind I ever saw.

What was also curious in this case was, that the antagonist muscles seemed to have lost their voluntary power of action while the others were acting involuntarily, as if they [the involuntarily acting ones] had been acting at the command of the will; and the antagonists accordingly keeping at rest.

Voluntary actions would appear to be as if the part were compelled to act by the will. Those actions arising from the state of mind would look as if they were only influenced by it.

Sneezing is an involuntary act, arising from a local stimulus, and requires a fuller inspiration than coughing.

We can imitate coughing and do it with any degree of inspiration; but we cannot imitate a sneeze, even when we fill the chest full, for it is a peculiar action. When I wanted to sneeze, when I had a rheumatic stitch in my back which deprived me of making a complete inspiration, I could not; but I could cough with the inspiration I was able to make.

The difference between coughing and sneezing is, that coughing is to clear the throat, sneezing the nose. In the action of coughing, the parts being moveable, adapt themselves to the operation, and it is an operation of their own. But, in sneezing, the part that is to be cleared is fixed, having no motion in itself; therefore, to diffuse the air over the whole surface as much as possible, the head makes a shake suitable, and turning with the blast of air.

Of the Senses.

Of Seeing.

The human is the only animal that judges of things in general by the eye. It is the predominant sense in man; therefore it becomes more improved than the other senses, when some accident has cast the scale in its favour for a greater frequency of action than them. We are comparatively inattentive to things by our other senses as they are less affected by things: the most willing and most useful are always first employed.

One reason why intelligence by the eye surpasses in accuracy [that by] the other senses, is that the object is or may be permanent, and may be compared with other objects, and considered in itself at the same time, at our leisure.

In brutes the sense of smell seems to be the most predominant. They only see and hear things to avoid them when at a distance, but not so much to distinguish them or examine their properties; and, indeed, as brutes are not capable of examining things with attention, the sensation of seeing does not strike them beyond the bounds of simple sight.

Of the Orbit.

The human kind and the monkey have the most complete orbits of any animals that I know. This is owing to the sphenoid bone making a considerable part of it by its union with the os malæ and os frontis: this makes an almost complete orbit. But there are three sorts of orbits: viz. the one we have given; the second, where the sphenoid does not go in [to the orbit] with the os malæ, nor make any considerable share of the orbit; so that there is a large hole between the orbit and the sulcus for the temporal muscle: this sort of orbit belongs chiefly to graminivorous animals, as horses, cows, sheep, deer, &c.: the third sort of orbit, which is the most incomplete, is where the sphenoid is like the former; but, besides that, the os malæ does not join with the os frontis; so that, in place of a hole, we have a large notch which is filled up in some animals with ligaments, in others with muscles and ligaments: this sort of orbit I think belongs to carnivorous animals, as dogs, cats, &c.

The human orbit is larger than in any other animal in proportion to the size of the eye.

From the human kind there is a gradual change of the [position of the] eyes from the anterior to the lateral parts of the face; for in many animals the eyes are placed on the sides of the head. Besides this change there is another, viz. from the [axis of the] eyes being at right angles with the face, to [their forming] oblique angles; that is, the axis [of the eyes] turning downwards. This last change is owing to the change from the perpendicular to the oblique position of the head.

The prominence of the eyes of animals, and their angular situation, is for the larger sphere of vision, and at the same time to see better any thing that is near their feet, as the head projects so much: this we see to be the case with the horse.

Animals which are either subject to be pursued, or which fight with their hind feet, have their eyes placed on the side of the head, and projecting, so as to throw the eye backwards. A hare, rabbit, many squirrels, &c. are of the first kind; the horse, deer, &c. are of the second.

Of the Choroid Coat.

That part of the choroid coat of the eyes of animals that is covered with a pigmentum album, is much thicker and stronger than any other part of the same coat.

Of the Motion of the Iris.

The eyes of animals have the motion of the iris increased in proportion to the size of the eye; but those that see in the dark have a greater motion of the iris than those that do not, in proportion to the size of the eye; and, perhaps, the oblong shape of the pupil is to allow a greater opening when it is brought to a round form than possibly could have been done if it had been always round.

It would appear from the disease of the eye called 'gutta serena,' that most probably the dilatation of the pupil was owing to elasticity; for although the iris cannot be stimulated by the retina being affected by light, so as to contract by muscular action, yet we can hardly suppose that the dilators [if there are such] can or will act so constantly as we find by the pupil being kept dilated for so long a time without tiring. (D. Anderson's case, p. .) [Where? asks Wm. Clift.]

I conceive the iris is endowed with a sphinctoric property, or power of contraction.

It is very common for the Angola cats to have the iris of the two eyes of different colours.

Of the Flatness of the Bottom of Eyes.

The flatness of the bottom of the eyes of some animals is, perhaps, to have distinct vision on more parts than one, not as in the human subject; for the flatness keeps a greater surface of the eye at an equal distance from the crystalline lens, therefore a greater [surface] at the focal point of distance; so that they can see lateral objects nearly as perfectly as direct ones; and we may observe that they do see lateral objects sooner or quicker than we do, and can throw the eye in different directions on the same object.

Of the Size of Eyes in different Animals.

There is a great difference in the size of eyes in proportion to the size of body in birds, and such difference is also observable in other animals. All those of the lion kind have remarkably large eyes, and all those of the bear kind remarkably small ones; and the intention of this is very evident; for we may always know the sphere of motion of the animal in search of its food, or in the common exercise of life, by the size of the eyes. Moles have very small eyes for that reason [in that relation]. This difference is not so much in animals that are always on the surface of the earth, as in birds.

Civilization appears to have considerable effect on the eyes. Many people have sore eyes; many grow blind. Are the same [effects as common] among savages? Civilized horses, dogs, &c., are more apt to grow blind than those animals which lead a more natural life, as deer, &c.

Two toads, after being under ground thirteen months, saw very well on a strong light being let in upon them.

Vide 'Book of Experiments,' vol. i. p. 84. [Quære: What Book is this?—Wm. Clift. Vol. i. implies another or more.—R. O.]

On Squinting.

Some people squint with one eye only, and never in common vision turn that eye to the object; it is then commonly turned in towards the nose; but when the other, or active eye, is covered, the affected eye then turns itself towards the object. Other people only squint in some directions of the eye, not in others; and this is according to the position of the object. If the object be nearly in the direction of the natural position of the [affected] eye, it will find little difficulty in directing its axis towards it. Other people, again, squint with both eyes alternately, respecting the position of the object. Such, I think, find it more difficult to turn the eyes inwards than outwards: they look at the object according as it is placed. If it is a converging squint, they look with the eye which is on the opposite side of the object; if it is a diverging squint, then the contrary.

This shows that the squinting eye is not able, or has not been habituated, to turn its axis to all the positions of the head with respect to objects, while the other eye is doing its office; for, when not under this circumstance, [when compelled to act by itself, the squinting eye] it becomes a good eye.

On Gutta Serena.

The disease called 'gutta serena' explains the power of motion of the iris, without which we could not form a just idea of it. Every impression [of light on the retina] excites a contracting power in the iris; which word impression says it is muscular; but as the iris also dilates, it was not so easy to say whether that was performed by elasticity or muscle; for a want of impression becomes a cause of action [a muscle, antagonized by elastic tissue, ceasing to act, permits the elastic motion]. In a gutta serena the iris is sometimes paralytic, and in others it is not, which, when under certain circumstances, can be discovered; and this I shall now consider under the four following heads:—

First, a total loss of the susceptibility of impression of light in the immediate organ of vision, in both eyes: *second*, such [loss] attended with a paralysis of the muscles of the iris: *third*, a total loss of the susceptibility of the impression of light in the immediate organ of vision of one eye: *fourth*, [such loss] attended with a paralysis of the muscles of the iris of that eye.

The first and second of these will produce no variety; because, as the stimulus of light upon the retina becomes the cause of action of the sphincter of the iris, it will be impossible for the iris [in the absence of that stimulus] to have any motion; and therefore it cannot be determined whether the sphincters are paralytic or not.

But the third admits of variety; for if the muscle is not paralytic, then we shall find that the stimulus of light upon the retina of the sound eye becomes a stimulus to the sphincter of the iris of the diseased eye; so that it will contract upon the light being thrown upon the sound eye, but not so much as if its own retina could have been affected by light.

The fourth admits of no variety; but it informs us whether the sphincter of the iris is paralytic or not; for if it does not contract upon the light being thrown upon the sound eye, we may be sure it is paralytic.

From all which we may judge, or reasonably suppose, that the dilatation of the pupil arises from elasticity, and not from muscular contraction; for its greatest dilatation is always attended with the greatest paralysis of the other parts.

Whenever a person is totally blind in both eyes, we find that the pupil is dilated to its full extent; but when the blindness is only in one eye, and [there be] no paralysis in the sphincter of the iris of the diseased eye, we find that the pupil will contract if the light is thrown on the sound eye.

Dr. Robertson's (of Kingston) case belongs to the [fourth condition]. There is a total paralysis of the left eye, both of the retina and of the sphincter; so that his pupil is very much dilated, and shows no signs of contraction when the light is thrown either upon the same eye or on the sound one. He was electrified, but it did him no good.

It is a common observation, that people, as they grow old, grow longer-sighted, *i. e.* the focal point appears gradually to move to a greater distance; but this is not the case. It is not a change in the position of the refracting power (which might be supposed to be a cause), nor an alteration in the form of the refracting power (either of which would oblige the focal point or whole shape of the eye to vary); but it is a defect in adapting the eye to near objects; for all such do not see distant objects better than formerly, but they do not see near objects so well as formerly.

The circumstance takes place in those only who have been used to see well objects both near and at a distance, and they lose the near sight; whereas those who only saw well objects that were near, have the natural focal point near, and continue to see them at that distance. But it must be remembered that they never had a great scope of focal action in the eye, or else they would have adapted it to more distant objects.

Every eye has a natural focal point, viz. that point which requires no exertion of the eye to adapt itself to it; whereas every object within, or beyond [the natural focal point], requires an exertion of the eye to adapt its focus to that object; and, the further [the object may be] from the natural focal point, either way, the greater the action required.

Of the Organ of Hearing.

The organ of hearing is peculiar to certain classes of animals; the more imperfect do not appear to be endowed with this sense. Insects certainly have it, if what is related of bees be true: however, I have not been able to discover the organ itself below fish[1], where it is very conspicuous.

It is a specific or peculiar organ for the sensation of sounds, the organ itself answering no other known purpose, which is not the case with the nose and tongue.

As the matter, or body, which is the first cause of sound, is not in contact with the organ, there must be an intermediate connexion or medium between the two. This medium is not confined to any one species of matter, which circumstance we may suppose produces a variety, and therefore the organ must vary in some degree according to the medium. The air appears to be the proper medium for us, but water is the medium for fish: however, even to us the medium is not confined to air, nor can we justly suppose that it is confined to water in fish.

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[1] [In the year 1782, Hunter stated, in his account of the Organ of Hearing in Fish, read before the Royal Society, "that the class called Sepia has this organ also, but somewhat differently constructed from what it is in the Fish."—Phil. Trans. 1782, p. 380.]

As sound is communicated by vibration, everything that does vibrate is either capable of producing sound or of increasing it; and perhaps air has the least power of vibration of any substance or modification of matter we are acquainted with: and, from experiment, water has been found to be a much better vibrator than air.

As this is the case, it would from thence appear, that an ear destined to hear in water need not be so nicely constructed as one in an animal whose way of life confined it to live in air; and accordingly we find them very different.

The vibrations of the medium of sound in many animals are increased before they reach the organ of sense by outworks, called the external ear; but this is not universal, belonging only to some of those whose ears are adapted to the vibration of air, and even in them it varies considerably in the different animals that have it: besides this, there are other increasers of vibrations, such as membranes stretching across the cavity, and other apparatuses besides.

The most simple construction of the organ of sound in any of the animals that I am yet acquainted with is that in fish. It is composed of three canals, describing nearly a circle each, and so placed as to make a triangle. Some of these communicate with one another at their ends, others not. They all open into one cavity common to the whole.

These canals, in this class of animals, are thin and transparent, and of a cartilaginous substance, pretty regular in size through the whole, excepting at or near to their unions, where they swell immediately into round cavities. They are placed in the bones or cartilages of the skull or head, and in canals or passages in these parts by much too wide for them, and are supported in these passages by a very fine cellular membrane. In many they project into the cavity of the skull. They appear to have no external communication whatever[1].

The cavity formed by the union of the whole is pretty large; in it there is a bone of a particular shape in some, while it appears to be a chalky substance in others, as in the skate, or ray tribe[2]; in all it is perfectly detached: it is very large in all the cod tribe. Besides the bone there is water, or a fluid, in the cavity.

The nerves are very distinct in this order of ears: it appears that they do not enter the cavity of these canals and spread upon their inner surfaces, as is generally supposed to be the case in the human ear, but seem to be attached to the external surface only, on which they spread so as to enclose a little more of the canal.

The next class of animals above fish is the *Tricoilia*. Their organ of hearing becomes a little more complicated, having a greater variety

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[1] [Hunt. Preps. Nos. 1560–1568.]

[2] [Ib. Nos. 1569–1574.]

of parts annexed to it. They have the three semicircular canals as in fish, but they are smaller and not so long. They lie in the bones of the head, where there are very wide passages for them: they unite into one common cavity, which has a chalk in it, as in the skate, &c.

The additional parts in this class of animals.—From this hall, or common cavity, passes outwards to the external surface a long small bone, which is broad at its inner end or base, where it makes a part of the hall: its outer end is attached to a membrane in most of this tribe; but to a cartilage in the turtle[1], which is of an oblong figure, convex externally and concave internally: this membrane is also convex on one side and concave on the other, in the same position as the cartilage. In most it is nearly in a line with the common surface of the body, as in the lizard[2], toad, frog[3], &c.; but it is placed somewhat deeper in the crocodile[4], which has something similar to an external ear; and it is covered in some by the common integuments or scales, as in the turtle. This cavity has an opening into the mouth, which is very probably no more than a duct.

The next class of animals above the *Tricoilia* is the birds. Although their ear is not much more complicated than that of the *Tricoilia*, yet it differs from it in some degrees. There is a neatness and precision in the structure that is not to be found in the *Tricoilia*. The semicircular canals in the bone are small and regular, and appear to answer the purpose of these canals. If there are also the membranous canals, then they are to be considered here as only linings to the bony. The hall is smaller than in the former.

The passage between the hall and membrane is enlarged and extended into the meditullium or cells of the bones of the head, and much more in some birds than in others.

The membrane of the ear is not so superficial, so that there is a canal, or a continuation of the same canal, beyond this membrane, leading to the external surface, which terminates in particular forms in different birds, which may be called an external ear, passage, or focal [cavity[5]].

The communication between the hall and membrane by means of bone is similar to the former [*Tricoilia*, viz. by a single bone].

There is a passage from the ear into the mouth [Eustachian tube].

The next class of animals above the bird is that commonly called quadruped. Their ear is much more complicated than any of the former, having actually more parts.

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[1] [Hunt. Preps. Nos. 1578–1580.]
[2] [Ib. No. 1576.]
[3] [Ib. No.1575.]
[4] [Ib. No. 1577.]
[5] [Ib. No. 1581.]

In this class the semicircular canals are similar to the former[1], but we have passing from the hall another or fourth canal, which is coiled upon and within itself, called cochlea[2].

The tympanum is extended some way into the bones of the head[3]; in some much more so than in others, as in the elephant, similar to many birds. The membrane is more internal than in the former, which, of course, makes the distance between that membrane and the external surface still greater. It is concave externally, contrary to the foregoing. The communication between the hall and membrane is by three bones[4] instead of one.

The passage from the membrane outwards is of considerable length; first in the bones, then continued further by means of a chain of cartilage, making a pipe, which when got to the external surface spreads in most into various forms and length, called the external ear. But this last part is not to be found in all: it is not in any of the whale kind, perhaps because the water is sufficient of itself[5]; nor is it of any size in the seal kind, perhaps because they are intended to search after their prey in the water, therefore not necessary. Nor are they to be found in many animals whose life is principally led underground, such as the mole; and perhaps because the earth assists considerably in vibration.

Query: Does the membrane of the ear increase the sound by increasing the number of vibrations, or by increasing only the same vibration? or does it only communicate the first vibration in the air? I should be apt to suppose the first.

All animals that have no external ear projecting from the head, as birds, lizards, and, I believe, many of the amphibia and sleeping animals, have their membrana tympani convex externally. How far this is a substitute for an external ear is not easily determined; but it would appear to have some such effect, as it is so universal. This class have no cochlea. Snakes and tortoises have no [obvious] external passage to the ear.

It is most probable that all animals which are capable of forming sound have the organ of hearing, but not conversely; for there are many animals that are not capable of making sounds themselves that have the organ of hearing, *e. g.*, fish.

In those animals which have external projecting ears and a consider-

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[1] [Hunt. Prep. No. 1603.]

[2] [Ib. No. 1599.]

[3] [Ib. No. 1601.]

[4] [Ib. No. 1602: from this passage it would appear that Hunter considered the os orbiculare as an epiphysis merely, as it has subsequently been regarded by several anatomists. See Carlisle, Phil. Trans. 1805, p. 201.]

[5] [Hunt. Preps. Nos. 1582–1598.]

able motion in them, such as hares, cows, sheep, &c., the ear describes a half conoid; but the circumference of that cone is not a section of a circle, but a side of an ellipse, with the long axis turned forward and backward. Besides this conoid motion, the ears have a rotatory motion, which attends the conoid; so that, when the ear is turned forward, the mouth of the funnel is likewise turned forward; and when the ear takes its sweep outward, the mouth of the funnel always corresponds to that motion. All this order or division of animals has the membrana tympani concave on its external surface; and as all of this class are *Tetracoilia,* they have all a cochlea.

Of Hearing.

The hearing of animals is either acute, distinct, obtuse or obscure; fitted to the various ways of life. Some animals have only one of those properties, while others have two or more.

1st. The 'acute' is for those animals, as mice, &c., that are a prey to others, by which means they avoid danger. The acute is also for those animals that prey upon others, as cats, &c., that they may the better find their food.

2nd. The 'distinct' is where the animal can distinguish between one sound and another, and take in the whole variety of sounds, such as the human kind, many birds, some beasts.

3rd. The 'obtuse' is for those animals that are not in danger of being preyed upon, nor is it their way of life to prey upon others.

4th. The 'obscure' is where animals cannot attend to, or are not capable of taking in or distinguishing, the variety of sounds. This is perhaps the largest class [or may characterize the majority of animals].

These four circumstances are the cause of such a variety of forms of ears.

The human kind, perhaps, possess the greatest share of any, especially of the second (quality), for they certainly can distinguish sounds better than any other animals.

The animals of the first class will require some degree of distinctness as well as of acuteness: as by the particular sounds they will judge of their proper food; as, in the case of cats, the sound of mice or rats, the fluttering of birds, &c.; and so of other animals according to their different kinds of food. The hearing of the third class will generally be attended with obscurity and indistinctness; for those animals, whose way of life requires no great variety of action, which are in no great danger themselves or endanger others, and which make no great variety of sound themselves, will generally be attended with the fourth [quality of hearing]. Animals will have distinctness in sound in proportion to their variety of action, and the great variety of sounds that they are in the habit of making themselves. The same thing may be observed of all the other senses.

Of the Effects of Sound upon Animals.

The effects that sound has upon animals may be divided into two. The first is simply sensitive; [the second reflective. The first is] when it affects the mind, and increases or diminishes the passions or the operations of the mind and body. This is only by simple sounds, varied in such a manner as to make the mind sympathize with, and, as it were, imitate the sound itself; by which means every part of the body sympathizes therewith, and is, as it were, put into such motions as are in unison or concord with the sound itself. It will not be an easy matter to account for this universal effect of sound upon the body, excepting it be in this way, that every part of the body is a conductor of sound, and of course is affected by it; and therefore the body is more ready to sympathize with the mind, or is more ready to receive the impressions of the mind, than if it had not that immediate connexion with sound.

Sounds having this universal effect upon the minds and bodies of animals can only be determined to some fixed object or idea; for, the moment it goes further in the mind than the immediate effect of the sound, it becomes a compound [idea] which the brute does not readily perform. It always raises in the human mind some fixed and determined passion, which may be called its 'first combination;' and then, again, that passion is directed to some object for which it has the easiest or greatest inclination. For instance, it will raise strange commotions in the animal system, plant the seeds of love or the susceptibility for love; and, if that man is already in love, these sounds will raise the passions in the mind which only wants the absolute object to fix or determine it; which [object] will be brought immediately into the mind, and will even increase the passion at the time in proportion to the simple effect it has upon the mind.

If a man has a turn for war, for conquest, &c., there are certain sounds that will raise him above himself, and make him feel irresistible; which will be determined to some fixed or general objects, just as his mind happens to be pre-engaged.

Nothing shows the effects of sound upon the body more than music. No man would be inclined to dance without music: the music also determines the kind of dance. Music is universal; the mind immediately feels its effects, and has recourse to it, as much as the body for food.

When we say that we are conscious of a thing, it implies two things, viz. 'consciousness,' and the 'thing.' But, in fact, it is only one thing, for consciousness is the whole. But from the manner in which we form consciousness, it is always referred to that manner; for, being in a state of consciousness is seldom or ever simple consciousness, but is compounded of a number. And, as consciousness arises originally from impressions, it must always suppose, or have, the impression at the time. The memory of hearing is always a compound of hearing and seeing; our remembrance of some sounds is owing to having fixed ideas annexed to them. The remembrance of sounds that we have fixed no ideas to is owing to our being capable of imitating them. If we had not this power we never could remember a tune, for instance. Sounds have two powers [sources ?]; the first is natural, as melody, sounds of fear, of anger, &c.; the other is from art, or is descriptive, by which we form ideas and make impressions on our passions: the first is of the head, the other is of the soul.

Animals have not those fixed ideas that we have; and the reason is, perhaps, that the sensation does not make the same impression upon the mind; for the impression on the mind is not in proportion to the sensation.

Seeing makes a strong sensation upon our minds, but not on the mind of a dog; for a dog will hardly know one he is not allowed to smell at.

The sense of hearing and seeing both require an action of the organ for distinct sensation. How far all the other senses are obliged to adopt themselves to the impression I do not know; but probably tiring or being accustomed to impression, so as to be insensible to it, may in some degree arise from the loss of action of the parts not adapting themselves to the impression.

Elasticity in bodies is the cause of sound, but they must be quick or short vibrations. Those bodies that give short vibrations, are hard and brittle, that is, they yield but little before they break, because their power of yielding is but short.

Of the Organ of Smell.

The sense of smell has an organ for receiving the impression called the nose. I suspect it is not so universal as what taste is; at least no organ that can give the idea is found in many of the more imperfect animals, and even in one tribe of the more perfect.

The organ of smell is a simple organ, being principally fitted for this sensation, and therefore presenting less variety than the organ of taste. However, the organ may be said to answer other purposes, as it gives passage to the air for respiration; so that the two purposes are answered by the same act. Besides, in some animals it is elongated so as to act as an extremity or arm, as in the elephant; or to dig, as in the hog: but in these cases this elongation is only to be considered as a useful part placed here for the convenience of the organ of smell, as this extremity is generally employed in the affair of food.

It is situated (as far as I know) near to, and above, the mouth in all animals.

In the Fish, which is the most imperfect animal that I know which has this sense, the organ is distinct from all others[1]; but in the Amphibia[2], Bird[3], and Quadruped[4], it communicates with the mouth. This situation allows it to be an assistant to taste, or rather the remote judge of proper food, while taste may be reckoned the immediate: for the body which possesses the quality of odour, need not itself be in contact with the organ, but only the parts possessing that quality raised into vapour, and that vapour making the impression; or the substance becomes soluble in water, and that water coming in contact with the organ, which becomes similar to taste. This happens to be the case with Fish, which is no more than smelling the medium in which they live, so that smell becomes much more extensive in its mode of reception than what taste is. Indeed, I believe it is in the same proportion more useful to those animals which have both: for many animals might do very well without taste, which would do very ill without smell, as the dog, fox, wolf, lion, cow, horse, &c. In such it would be extremely inconvenient not to have it, for the operation of tasting is considerable, requiring a movement of the body to be tasted, and also to undergo a change, while smell is done at once.

As the mode of application of the matter which makes the impression in smell is more delicate than in touch, the organ is also more delicate in its structure. The structure in the sensitive part appears to be pretty much the same in all the animals possessing this organ: it is a spongy or soft membrane and very vascular; which is known by injection. It does not appear to be covered by any cuticle. The acute reception of smell by the mind is caused by quantity; therefore the surface of impression is extended or increased; and more especially in those animals which are to, or can, distinguish their food by this sense alone, and still more so in those which are to go in search of it by the smell, such as the dog, &c.

The operation of smell is performed, I believe, in the act of respiration in all animals that breathe air; and in all, excepting man, this

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1 [Hunt. Preps. Nos. 1527–1530.]
2 [Ib. Nos. 1531–1535.]
3 [Ib. Nos. 1536-1540.]
4 [Ib. Nos. 1552–1559.]

operation of respiration is principally performed through the nose, so that the passage in them answers two purposes.

Smelling is no more than the atmosphere or medium in which the animal lives being impregnated with such matter as to make an impression on the organ; therefore the air becomes the medium to the aërial, and water to the aquatic. There is, however, a tribe of animals whose construction is that of the most perfect, but which live entirely in water, which search and catch their food in water, yet from their general construction they must breathe air. [Whale and porpoise kind.] Here arises a difficulty: an animal to breathe air which it need not smell, and not to breathe water which it should smell, if smelling were necessary; and to make a water-nose, was making the animal, in this respect, like a fish, which would be deviating from the first principle [1]: therefore nature has made them entirely without the organ of smell[2].

Of Smelling.

The third sense is that which is called smelling: it is where the matter is too refined to be able to affect any of the other senses. To affect this sense it must be in vapour, but it does not entirely depend upon matter being in vapour; it most likely depends upon a particular modification of matter, or a particular modification of vapour which naturally arises out of the volatile body. Whether the impression is by impulse or by simple application is not so easily ascertained.

This sense has a degree of refinement above taste; and is, much in the same proportion, less hurtful in its disagreeable sensations. It is so connected and so subservient to taste, that I am inclined to think that we can in some measure judge of the taste of a body from the smell, and *vice versâ*.

Whether or not this imagination arises from custom, as we taste but few things that we have not smelt before we taste, may be a question. The moment that we smell food, we that instant have an idea of its taste; just as when we hear a bell ring we have an idea of the bell. But what is most certain is, that smell and taste give us general ideas of one another; for, whatever is rich and fragrant to the smell, is also such to the taste; and I should suppose that whatever would give taste in solution, would give smell in vapour, and perhaps such a smell as would give a pretty just idea of the taste.

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[1] [The 'homological' principle, or that of Unity of Plan.]

[2] [This was probably written before Hunter had dissected the piked and true whales, in which he discovered the organ of smell. See Animal Economy, p. 377, and Hunt. Prep. No. 1546.]

The sense of smell in the goat is so acute, and the nicety in their food so great, that they will not eat anything, such as a piece of bread, that has been breathed upon by a human being.

Quadrupeds seldom breathe through their mouths, almost always through their noses, so that it may be said they are always on the scent; for the nose seems to make up for the deficiency of the eye, and they chiefly receive information by the nose. For this purpose, too, the nose is more free from mucus in other animals than the human, so that the glands are not so numerous. I believe that herbivorous animals always breathe through the nose, and this constancy fits the nose better for choosing the food.

Of the Organ of Taste.

The sense of taste has an organ fitted for its reception, and nerves for its conveyance. It appears to have a greater analogy to touch than any of the others, and appears to be as universal, few animals being endowed with touch but what are most probably also endowed with taste.

This organ is placed as a sentinel at the beginning of the passage into the stomach, called the mouth, lying on the lower surface of that cavity, so that the substance to be tasted comes more readily in contact with the organ. It gives intelligence to the mind, which permits only such food to pass as is in general salutary.

It is, in most animals, a projecting body, but much more so in some than in others. Its shape is various, being in general nearly the shape of the lower jaw, in those animals that have that bone, as in Fish, Amphibia, Birds, and Quadrupeds; but in many other animals the shape is adapted to the various purposes or uses it is put to, as in the bee[1], the whelk[2]; and in others it varies its shape considerably, according to the various motions it is performing, as in the toad[3], chameleon[4], wood-pecker[5], ant-bear[6]; where, when at rest, it is of the same shape with the jaw, but when in use it forms itself into another shape.

It has motions in all animals, but more so in some than in others: when its motion is least it is perhaps nearly simply the organ of taste, which is probably the case with most fish[7]; however, in many fish it serves as a retainer of the food, having teeth placed upon its surface, as

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[1] [Hunt. Preps. Nos. 1439–1440. See Animal Economy, p. 455.
[2] [Ib. Nos. 1441–1444.]
[3] [Ib. No. 1451.]
[4] [Ib. Nos. 1453–1455.]
[5] [Ib. Nos. 1477–1479.]
[6] [Ib. Nos. 1502, 1503.]
[7] [Ib. Nos. 1447–1449.]

in the trout[1], and many other fish. The grinders and retainers are placed at its base. But in all those whose motion [of the tongue] is considerable, it becomes a very compound instrument: it becomes in them not only the judge of the food brought in by other means, but it becomes the immediate instrument for providing, as in the woodpecker, chameleon, toad, bee, fly, whelk. It is most probably the conductor of the food into the œsophagus in all animals. Indeed, this instrument of taste is extended to various purposes, as in the lion[2] and cow[3] kind, for scratching; in all quadrupeds and birds, for the modulation of sound.

Its structure varies equal to the various purposes, but the structure fitted for receiving the impression of taste is pretty similar in them all. The exterior or upper surface is principally the organ of taste, as the skin is the organ of touch. It is in general very villous, but this differs very much in different animals, which arises from animals appearing to differ very much in their acuteness and delicacy of taste, some being more obliged to the sense of smell than taste for the formation of their judgment in food.

The tongue in all animals is most probably covered by a cuticle, at least in all that I am acquainted with. This covering, in those which (we may suppose) have the most acute taste, is very thin, as in the human subject[4], monkey[5]; but in many others it is extremely thick and hard, being of the consistence of horn, such as the little claws on the tip of the lion's tongue, the horn on the tip of many birds' tongues.

The tongue in all animals is a compound instrument; its uses may be reckoned three: viz. a sense, the voice, and several [mechanical] purposes, as scratching, &c. As a sense of taste, or rather with respect to food, it is capable of two uses; first, for taste; and secondly, for catching the food in some animals, and for modulating it in all, or that action which may be called the first operation of deglutition.

These different uses are not in an equal degree in all animals; some having one of these uses in a considerable degree, while [the other functions of the tongue may be] weak, and *vice versâ*. In most animals there is but one organ of this kind, as in the human, birds, snakes, fish, &c.; but there is a class of animals that have a great many such, as the priapism[6], sea anemone, &c., which may be called the 'polyglotts.'

The sense of taste is perhaps stronger in the human than in any other animal of the same class; and most probably this arises from

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1 [Hunt. Preps. Nos. 394, 395.] 2 [Ib. Nos. 1509–1513.] 3 [Ib. No. 1594.]
4 [Ib. No. 1524.] 5 [Ib. Nos. 1517–1523.]
6 [Ib. No. 1438: "Part of the priapus showing the tentacles, which in this animal serve the purpose of tongues." The specimen is of the *Holothuria tubulosa*, Lam. See 'Physiological Catalogue, Mus. Coll. Chir.' 4to. vol. iii. p. 63.]

there being a deficiency in the sense of smell in the human species; and we find that the tongue in the human species is better calculated for taste than it is in many other animals. Its surface is vastly increased by the villi and papillæ, and by its cuticle being very thin. It is of considerable use in the first operations of deglutition, such as the management of the food in the operation of mastication, and, when the food is masticated, to conduct it to the œsophagus. It makes, perhaps, a principal part of the instrument of sound. The other uses (which in many other animals are considerable) are but few in man, the hand supplying the deficiency.

Of the Progress of the Senses, especially Taste.

It is some time before children are sensible of different sensations; everything that strikes the senses is the same; but by degrees they begin to distinguish and separate one from the other; first, by the agreeable and disagreeable [impressions]. A new-born child is not sensible of taste: all tastes are alike: the whole business of a child, at first, is to swallow everything that touches the lips; nor have they at this time the power of rejection.

A child laughs when it is but a few days old; and this cannot arise from any pleasing ideas, as it cannot have formed any; but it must arise from an agreeable state of body: not from mere absence of uneasiness, or perfect tranquillity, or insensibility, but from a certain irritation that is agreeable, without thought. Some sounds have the same effect at so early an age. Children swallow whatever is put into their mouth, let it be ever so (what we call) ill-tasted; this shows that taste is some time in forming, and requires a variety of impressions to cause even agreeable and disagreeable tastes; besides, at first children have not the power of rejecting; they gain that by habit.

Relative Durability of Impressions in the different Organs of Sense.

The sense of smell is the least durable of any; when the application is continued we very soon lose the sense of it. Taste has something of the same kind. Sight is the most permanent; we always see when the object strikes the organ of sight, excepting when the mind is attending to something else, or when the organ is tired, as when going to sleep.

Of the Organ of Touch.

Although every part of an animal feels, yet the skin and all exposed parts are perhaps the most sensible of the simple impressions of touch*, and not only most sensible, but most capable of distinguishing the

* Here I would be understood to make a material distinction between the sensation of touch, and irritation to action or pain.

different impressions, such as roughness, smoothness, heat, cold, &c. However, many internal surfaces are also capable of communicating many of the same sensations, such as the mouth, rectum, and urethra, for we are very sensible in those parts of heat, cold, &c. Nevertheless, we find the superficial surfaces more capable of giving with nicety the superficial structure of bodies than any of the others; and this much more so in some parts than others, such as the skin on the ends of the fingers, lips, glans penis, even the tongue. Perhaps this perfection of touch in some of these parts may in some degree arise from habit; however, we find the organ more perfect in those parts than in others, being covered by a structure which is fitted for the purpose of sensation, called villi, not of acute sensation, but of delicate, or perhaps more frequently of distinguishing, sensation. This is confined by an increase of this structure in those parts that are most sensible, as on the ends of the fingers, lips, &c.; and also in many animals where it was necessary for them to have the parts well defended from external injuries; such we find in all those animals which have hoofs; there the villi are very long and placed very thick and close[1].

This structure is much better adapted for sensation than what a smooth surface possibly could be, because as we always feel a rough surface or body better than a smooth one, this roughness in ourselves supplies in some degree the place of roughness in the body touched.

This structure, fitted for the impression of touch, is perhaps perfectly mechanical, being only adapted for the impressions of resistance*.

Of the Voices of Animals.

All animals of the same species have the same voices. For instance, all horses neigh; all dogs bark; let the differences be ever so great in every other respect, as to size, shape, or colour. A lion therefore is not a cat, and indeed it is not in other respects. (*Vide* Dissection of the Lion.)

Blacks from the Guinea coast never articulate sounds so clear, so distinct from one another, and so sharp, as the Whites do. Whether this is a defect in the organs themselves arising from the form of the mouth, lips, &c., or from any other of the organs of speech, is not easily determined. Phyllis, a negro poetess, left the coast of Africa so young that she had not the least remembrance of it. She was taught to read and write and became a critic in the English language, but

* The sensation of heat and cold may be brought in as an objection to this idea; but heat and cold require perhaps no peculiarity of structure for receiving their impressions, it being that of simple sensation only, as of pain, &c.

[1] [Hunt. Preps. Nos. 1410–1413.]

still had some of that thickness in her speech which all the Guinea Africans I ever saw have.

The cuckoo being educated by [or brought up with] various birds, and always having the same voice, is a proof that the young do not take their sounds or voice from the parents.

OBSERVATIONS ON GENERATION.

On the distinctive Characters of the Sexes.

All the most perfect animals are of two sexes, male and female. The chief distinction between the two is in the parts of generation: but, besides this true and certain one, there is [an outward] character peculiar to each. The male may be always distinguished from the female by his noble, masculine, and beautiful figure. This holds good in all animals, but in fowls it is most remarkable[1]. This difference depends on the effects that the ovaria and testicles have upon the constitution, which is not till a time of life when they become useful; so that both sexes are alike at an early period of life, some time before puberty [excepting simply having different parts of generation]; but about the time that they both are fit, or rather becoming fit, a change in disposition takes place both in make and in beauty; but this is most remarkable in the male. He, as it were, leaves the female state and undergoes a kind of change or metamorphosis like the moth, the female remaining more stationary; however, the female is not quite so, for she acquires properties peculiar to herself. These properties in the female, although they would appear to differ or rather appear opposite to those of the male, yet, in another point of view, they will be found to have a certain similarity, and which similarity is only known by bringing the male and female under the same condition; this is by castrating the one, and spaying the other. In either case the operation produces a [kind of] third animal, different from either male or female, and of course different from what the castrate would have been if it had been allowed to undergo the natural changes arising from the retention of the natural parts. This 'third animal' is more like the female than the male, because the male undergoes a greater change than the female does. The female in her changes follows the male in a small degree; which change gives the difference between this 'third animal' and the female.

To put this in a simple point of view, we may observe that at one time of life, the male, the female, and the neuter, are all three

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[[1] The diurnal *Accipitres*, or Birds of Prey, form an exception to this rule; the female being the larger and 'nobler' bird.]

equal [or similar], viz. when very young. Take of any one genus, for example pigs, at a very early period of life, two males and two females; geld one male and spay one female, and observe the gradual differences as they take place. It will be observed that no difference takes place for a while; and, when it does, it will be first observable in the male; for as the male undergoes the greatest change, so the difference is sooner observable: the male also is fitted at an earlier period of life for his purpose than the female, therefore [effects of castration show themselves] sooner in him.

The female then begins to change, following in a small degree the male; but as the change in the female is in a much smaller degree, she, as it were, remains more like the castrate than what the male does. The castrate, both of the male and female, goes on equally [in a course], as it were; natural to an animal which has no purpose to answer but that of its own support; and therefore it may be reckoned the standard, and the male and female the variations.

The differences between the male and female in its fullest extent, exclusive of the parts of generation, are 'size in general,' 'size of particular parts,' and 'disposition to be fat.'

After these general observations let us illustrate them by example:

First, as to size in general. Those animals, of which the male is larger than the female, have the castrate of either still less than what the female is; so that the female has in some degree followed the male.

Secondly. Those animals, of which the males are smaller than the females, have the females smaller than the castrates; so that the males are comparatively contracted in their growth, and also the females, but in a less degree. Instances of this we have in many animals. The black cattle are strong instances of it. The bull is smaller than the cow, and the cow is smaller than the ox, or than the spayed cow. The swine-kind are also convincing instances of it.

Thirdly. Those animals, of which the males and females are of nearly the same size, have their castrates nearly the same, viz. horses.

It may be impossible to show the use of change of form [in the two sexes], from what may be called effeminate to the contrary. Yet it would look as if it were to please the vain ideas that the female has, which Nature has given to all animals,—a passion that was very necessary, for it prompts on some and gives a kind of happiness to others.

That this change depends upon the testicles and ovaria is plain. This we see, that in the castrated cock the comb does not grow, nor his spurs; he has not the tail nor the shining feathers. Castrate a young bull, and his neck will not grow; but the hair of his forehead and his horns will grow to the length of those of a cow, or longer. Take a boar, and his tusks will not grow. In the eunuch the child's voice keeps the same [at maturity].

Distinction of the Sex inappreciable at early Age.

The distinction of the sex, exclusive of the parts of generation, is but very small in childhood and youth. Boys and girls are very similar in all their features when first formed; even the parts peculiar to each are similar to one another [in the embryo]; both seeming to shoot out from one point, but each on a different plan; therefore they become very different by the time they arrive at perfection. We not only find this circumstance in the most perfect animals, but in the less perfect, viz. Birds. All young birds, male and female, are very much alike: the distinction does not take place till they cast their first feathers; and then the second begins to distinguish the sex, viz. the cock becoming different from what it was before.

It is to be observed, that in the whole progress of separation [departure from the common character], it is always the male that goes off from the female. However, the female has her distinctions; but they are not all peculiar to her: the male has the very same, besides those peculiar to himself, viz. the adult female has the hair on the pubis, so has the male; the swan has the second growth of feathers, so has the male.

Acts of Generation.

The parts of the male and female, in their natural state, bear a pretty near proportion with regard to variety; but as the female parts are subject to changes from impregnation, this produces a variety of itself; and as these changes vary in almost every anima., it produces in the whole a vast variety in the one sex more than [occurs] in the other.

The act of generation seems intended by Nature to give pleasure. Those animals that are male and female, and those which are hermaphrodites, have it in a strong degree. How far those have it which cannot be called of either sex, or wholly of both, such as the Polypus, is not easily determined; but in the others it is obvious.

In those that copulate, the pleasure is in the copulation, whether viviparous or oviparous. Those that do not copulate are oviparous, and have their pleasure in the evacuation of their eggs; such as frogs, toads, and all the roe-fish kind. This pleasure, most likely, is not in the simple passage of the eggs; but, in one class, in the embrace of the male, although there is no insertion; and in the roe-fish it would seem to arise from the rubbing their belly against some hard body.

Mental Influence over the Act of Generation.

The act of generation arises from two causes of motion: one an internal stimulus in quest of external influence, the other external and mechanical. A strong effect upon the mind by means of nerves is capable of doing it; so that the action of the nerves is similar to external influence. A dream does it more completely, which is a stronger action of the mind than when awake; for, when awake, the mind is fluctuating between the delusion of idea and the truth, which only produces half the effect; but in the dream it is all idea, or the mind is allowed to act on the parts with full force; therefore the nerves do not act of themselves, they only become a stimulus to other parts.

Relative Pugnacity of the Sexes when in Heat.

Most males fight for their female when she is in heat; but I believe no two females in heat fight for the male:—the human perhaps may be considered as an exception to this rule; but, if it is, it most probably arises from reason joined with the strong principle of desire of being possessed.

On the Seasons for Breeding.

Animals which are obliged to have recourse to the fruits of the earth for food for their young, breed early or late according to the season for their respective foods, which 'season' generally includes warmth; and animals which have the power of provision within themselves, breed according to the warmth of the season, joined with the modes of preserving their own heat, either by the economy of the parent, as [exemplified in the nests of] mice, rats, &c., or by their own covering, as in the case of lambs, &c.

Warmth brings forth seeds faster than cold, therefore there is no determined time for their development, but that which relates to heat. Warmth also brings forth insects from the egg sooner than cold, and makes eggs hatch faster. But does a warm climate make a woman go less than nine months? or a cow, &c., less than the usual time in cold climates? Precocity in the human species is a consequence of warm climate.

On the Organs of Generation.

Relation of Vesiculæ Seminales to Size of Testes.—The testes of animals, with or without vesiculæ seminales, are pretty much upon a par with regard to size. If the vesiculæ seminales were really such, we might suppose that the testicles would be much less in those animals that have the 'vesiculæ' than in those that have them not; as a small body that is always secreting, is capable of secreting as much in twenty-four hours as a much larger one is in five minutes[1].

The testes in all animals, so far as I know, are oval. One might suppose that this shape would give an easier exit out of the abdomen; but the testes of fowls, &c., are of the same shape.

Tunica Vaginalis Communis.

In the adults of [mammalian] quadrupeds, the tunica vaginalis testis communicates with the abdomen, but it keeps nearly the same size, between the testes and abdomen, that it had in the fœtus; so that this part of the canal does not increase in proportion with the lower end where the testicle is, and with the abdomen.

The origin of the spermatic arteries and veins of the ovaria are the same in all animals, let the situation of the ovaria differ as much as possible. The origin of the spermatic arteries and veins of the testes and of the ovaria is the same in all animals.

The spermatic vessels go out from the abdomen higher up in the quadruped than in the human; they pass under the peritonæum along the psoas muscles before they get to the lower part of the cavity of the abdomen, so that any pressure upon this part makes it act like a valve.

Of the Prostate Gland.

I suspect that the prostate gland does not go round the urethra [in the human subject], and that there is none of this gland upon the anterior part [of the urethra]. The reason that I suspect this is, that I have seen that gland twice[2] swelled and diseased, but none of the disease was on the fore part.

Fowls have no bags similar to what are called the 'vesiculæ seminales,' and one would naturally think that they had the greatest use for them, because the cock treads the hen at once, without any previous preparation; but as the semen must be ready secreted for such quick demands, nature has enlarged the terminations of the 'vasa deferentia' in him. This would seem to support [the opinion of] the use of these bags in

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[1] [In the feline tribe, hyæna, civet, weazel-tribe, which have no 'vesiculæ seminales,' the testes are proportionally smaller than in some quadrupeds, boar, *e. g.*, that possess them.]

[2] [This must have been an observation made a great many years ago, as Hunter must have seen many such cases afterwards.—WM. CLIFT.]

animals [as being reservoirs[1]]. I observed the same in the dog-fish; the termination of the vasa deferentia were enlarged and full of semen, which was white and creamy.

Generative Secretions tested by Taste.

The semen would appear, both from the smell and taste, to be a mawkish kind of substance; but, when held some time in the mouth, it produces a warmth similar to spices, which lasts some time.

On the Mucus of the Urethra.

The fine transparent mucus of the urethra is strongly impregnated with sea-salt, which is immediately known by the taste. The use of this mucus would seem to assist in lubricating the inside of the vagina; for it is similar to that from Cowper's glands in women, and it is only secreted in the time of copulation; none is to be found at other times.

Of the Penis.

From experiments, it would appear that the erection of the penis is not through a greater influx of blood at one time than at another, but from a stagnation in the common passage of the blood through the part, as in the veins when we tie up an arm[2].

The penis sympathizes much with complaints of the bladder, and even with complaints of the kidneys; for when either of their parts are irritated, the pain is mostly in the glans penis; but if either are much irritated, then they become sensible of it*.

Penis of the Horse.

The cavernous structure of the penis of a horse is plainly muscular to the eye[3]; and, from circumstances, there is reason to suppose that the human [corpus cavernosum] is the same; for we find that the penis is sometimes, in erection, much larger than at others, yet equally turgid at both times. When in the largest state, it is always at a time when the parts are warm and relaxed, when the whole constitution is free from all kinds of rigors; it is largest, *e. g.*, when erect in the warm bath.

* *Vide* Dissections of Morbid Bodies (No. 6).

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1 [See the more mature conclusions of the author on this subject, in his work 'On the Animal Economy,' pp. 20–29.]

2 [See Animal Economy, p. 32, and Note.]

3 [Hunt. Prep. No. 2549. See Animal Economy, p. 30, where Hunter states that in a horse just killed the cells of the cavernous structure 'contract upon being stimulated.']

On the contrary, when the body is cold, and when the penis is exposed to cold, it does not swell to that size that it does in the other case.

In both these cases it is equally rigid, and is not capable of further distention. It is well known that cold applied to the skin becomes a stimulus to the muscles of the body, and of course to [those of] the penis; so that it is not capable of its full distention [under the influence of cold].

Of the different Kinds of Female Parts of Generation, commonly called 'Ovaria.'

The first kind includes those where the ovaria exist in the unimpregnated state[1]; and the only difference between that state and the impregnated one, is the increase of the size of some part of these ovaria. Probably the only part which constitutes the ovum in the unimpregnated state, is, in birds[2], the part which forms the cicatricula in the increased state, and that the increase is due to the addition of the yolk only. The class called amphibia[3], and the class of fishes called cartilaginous[4], also present this kind of ovaria. All that exemplify this kind have the oviduct, which I believe adds to the egg a second part, viz. the albumen, so that the eggs of such are, I believe, always composed of two parts.

The second kind includes those which have no ovaria in the unimpregnated state, and where there is a new creation every time they are preparing or prepared for propagation, so that the whole body of the ovarium is removed each time they do propagate. These have no oviduct; and it is probable from this circumstance that the ova are only composed of one substance; such I believe is the case with all the pectinated gill-fish, or those which have roes[5].

The third kind would appear to be a mixture of both, partaking of the first from their having oviducts; and of the second, from their having no ovaria in the unimpregnated state. The ova are, therefore, entirely formed at the proper seasons, as in the second, but differ in respect to situation; for here they are formed in the oviducts themselves. The number of these ducts is increased in many, so as to allow for the proper number of eggs, while in others there are only two ducts.

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1 [Or rather 'unexcited' state; the ovary of the bird acquires its full size without any impregnation.]

2 [Hunt. Preps. Nos. 2726, 2730, 3380.]

3 [Ib. Nos. 2695–2724.]

4 [Ib. Nos. 2676–2694.]

5 [Ib. Nos. 2660 (Eel), 2661, 2662 (Salmon), &c., 2663–2674.]

Of the first of this class is the moth[1] and butterfly; of the second, the beetle[2]. The structure of such eggs I have not yet ascertained.

Of the Oviducts.

All oviparous animals[3] have one or two oviducts. Fowls have one. The amphibia and lizard-kind have two. These have nothing like a uterus or a vagina, and have a common passage to the oviducts and rectum.

Oviparity belongs to the inferior order of animals, both as to powers or principle, and as to size.

Of the Fallopian Tubes.

If we consider the use of the fallopian tube in animals, where its use is very evident, and then apply that use to where it is not so self-evident, we shall be led, in some measure, to infer the same use to it in them also, although, perhaps, not to the same extent of use. All the viviparous classes have them. Many of the oviparous have them, and many are without them. It is in the oviparous that we are to examine their use, and then apply that to the viviparous[4].

Double Uterus.

Many animals have two uteri, viz. the rabbit[5], a particular kind of hog called the 'peccari,' 'Le Cabiai[6],' &c.

Of the Uterus.

The operations of the uterus, when impregnated, do not go on in all parts of that viscus at the same time, but only where the fœtus is. For example, the increase of size of vessels, the alteration in the structure of the uterus itself, both of which appear to depend on the increase of the size of the uterus, do not take place save at those parts which are distended by the increased growth of the fœtus[7].

The woman who died at the London Hospital in consequence of a

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1 [Nos. 2602–2605. I have described the tubes where the ova are developed, as the 'ovaria,' agreeably with the accepted determination of their nature.—Physiological Catalogue, 4to. vol. iv. p. 114.]

2 [Ib. Nos. 2641–2643 (*Melolontha*), 264–45 (*Geotrupes*).]

3 [See p. 34, where Hunter defines his proper 'oviparous' classes, excluding the roe-fish.]

4 [The 'fallopian tubes' in mammals are homologous with the major part of the 'oviducts' in oviparous Vertebrata possessing them. They transmit the ovarian ovum, and add material to it.]

5 [Hunt. Preps. Nos. 2743, 2744.]

6 [Ib. No. 2751: the preparation is of the *Aguti* (*Dasyprocta*): the &c. includes the *Marsupialia*. Ib. Nos. 2735–2741.]

7 [This is best exemplified in the long divided uterus of rodent and other quadrupeds. See Hunt. Preps. Nos. 3469, 3470.]

bubonocele, and who had the ovaria, fallopian tube, &c. in the hernial sac, had also a tumour in the substance of the uterus at its fundus; but very probably this substance grew on the inside of the fundus. It was about as large as a small fœtus's head, and did not affect the lateral parts nor 'cervix' of the uterus. But what was most remarkable was, that the substance of the uterus was not diminished in thickness where it was extended by the tumour, but, when cut into, presented the appearance of a pregnant uterus of corresponding size, viz. the same thickness and softness of texture; the veins forming what are called 'sinuses,' which cause the softness of texture and the lamellated appearance. The parts of the uterus not concerned in this tumour were of the usual texture*. She died in the time of her menses, which were confined to the cavity of the uterus.

The size of the nerves of the uterus do not alter in impregnation.

Of the Round Ligaments.

Those of a mare had plainly red muscular fibres passing up from the [abdominal] ring along them, exactly similar to the cremaster in quadrupeds where the testes have not come down, or in those where they never come down (as is sometimes the case in sheep). The round ligament is an inverted cremaster; and in the female would seem to be something analogous to the nipple in man, viz. an imitation of the opposite sex.

Vagina.

All viviparous animals, excepting the '*viviparous ex ovo*,' *i. e.* the viper, and perhaps the piked dog-fish, have a vagina[1], which is placed in the middle of the body, before the rectum, and has one or two uteruses at the farther end of it.

The veins of the parts of generation in the female increase to an immense size when impregnated.

The veins of the testes of the skate-kind also increase very much at the season of copulation. In the female skate the veins of the ovarium and fallopian tubes [oviducts], and of the glandular bodies, are so enlarged as to surround them like cellular membrane.

Of the Pudenda.

The skin of the pudenda grows redder and redder to the years of puberty, and seems to have little or no rete mucosum. When a woman

* *Vide* Preparation. [Quære: Where?—Wm. Clift.]

[1] [The homologous part, in *Marsupialia*, is divided or double, like the uterus.]

is with child these parts grow darker, even darker than the other skin, like the nipple; which colour does not terminate at once, but is gradually lost. This darkness extends to the 'nymphæ' and 'carunculæ myrtiformes.' In a woman the vulva is before the rectum; in a hen it is on one side; in the lizard, &c. it is on both sides; in the shark, skate, &c. it is above, or rather behind, the rectum[1].

The clitoris in all animals is similar to the end of the penis of the male of the same species.

On the Source of the Menses.

A young woman died at St. George's Hospital. There was some blood oozing out at the vagina; therefore I suspected that she had died while the menses were upon her. I took out all the parts and injected them. The parts became more red than common: the fallopian tubes, the outside of the uterus, the inside, and the vagina, were loaded with injection. In the cavity of the uterus was found extravasated injection; and on the inner surface there were dots of injection, as if swelled out at the end or opening of a vessel, just ready to drop off.

On Copulation.

Frequent copulation seems to be the most violent discharge that can attend an animal; yet the quantity discharged is very inconsiderable. It is nothing to the discharge of a blister, a sore, a purge, a cold, or a bleeding; yet it shall relax and weaken more than any other. In explanation of this, it is supposed that the most balsamic part is lost to the constitution; but this is mere conjecture, arising from a notion that the fluid must be very fine that can form an animal; but surely, when this animal is formed, it is not a bit more 'balsamic' than the parents it sprung from; and we cannot suppose that it becomes less balsamic in course of being formed. I believe the truth is, that the semen differs very little from common mucus; it may have something more of the volatile salts in it, as it is the only juice that has any degree of smell when newly secreted. What I should suppose is the cause of this effect of copulation, is the spasm produced for the discharge of the mucus secreted. Spasms of all sorts weaken much; the cold fit of an ague weakens as much as anything we know of; and fainting fits relax the system so much as to take off the violent constriction of a fever.

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[1] [See the series of Hunterian Preparations illustrative of the cloacal structures, Nos. 744–756, and No. 2825.]

The great weakness arising immediately upon the ejecting of the semen does not arise from the evacuation of the fluid out of the circulation, but from the universal spasm produced; for like all fainting fits it produces sleep; and in many it is so great as actually to produce actual fainting, especially in men of irritable habits. Indeed, before this spasm comes on, the semen is secreted; therefore the constitution is already deprived of it; and the same spasm happens when there is no secretion, as in many who have been using venery too frequently. Perhaps the [final] reason of this spasm weakening so much, is to prevent the testes from secreting till the constitution is again restored, and also to carry off the universal stimulus when it is not lessened nor carried off by the secretion, but rather frightened by it. All this is from a design to limit venery; for, as the pleasures arising from such practices are too great to be checked by reason, it was necessary that a stop should be put to the desires, and that a want of desire should put a stop to the secretion; for this stimulus is not simply taken off by the spasm, but the whole animal is considerably weakened.

It would appear that the female is not so desirous for copulation as the male. We find in most animals, if not in all, that the male always courts the female; that she requires being courted to give her desires, otherwise she would not have them so often. Lord Clive's zebra is a strong proof of this. When she was in heat they brought a common male ass to her, but she would not admit his addresses. Lord Clive ordered that the male ass should be painted similar to the female zebra; and this being done, she received him very readily. In this curious fact we have instinct excited by mere colour; for we cannot suppose that she reasoned or judged of the male from herself, as she never could have seen herself so perfectly. Colour had so strong an effect in the present case, as to get the better of everything else. But the male did not require this; [she] being an animal somewhat similar to himself, was sufficient to rouse him.

My brown cow generally wanted the bull every three weeks when she was not allowed to take him. Sir John Chetwode told me that cows well kept, if not with calf, would take the bull every three weeks.

My cow at 'Earl's Court[1]' had some blood come from the vagina; we suspected she was not well; but a day or two after she took the bull.

Another cow at Earl's Court took the bull several times, but did not conceive. The distance between each time was about three months, but not regularly so. I intended to dispose of her, but gave orders always to give her the bull till I could dispose of her. After being at

[1] [Hunter's country residence, at Brompton.]

the bull the last time, she fell off her milk the day following, and there was a change in the milk. I suspected that some change was going on in the constitution, and therefore kept her. For five months we could not tell whether she was with calf or not; but she had not taken the bull all this time. Before the sixth month she proved with calf.

A she animal that has more than one young one at a time, as, *e. g.*, a goat, &c., can be impregnated by more than one male. I had a she goat that had, at one time, two young ones to two fathers. The fathers were very different sorts of goats; one was very large, rough, white, and had large horns; the other was small, smooth, black and grey, and had no horns. The young ones the same [showed respectively the same differences].

Case of Superfœtation in a Negro Woman.

"Dr. H. Allen of Bardadoes, now of Hatton Garden, gave me the following account of a case which happened to a negro woman belonging to the estate of Mr. Mapp, a practitioner in medicine in Barbadoes (and Dr. Allen's father-in-law), about the year 1750. A negro woman went the full period, and was delivered of twins, one black and the other a mulatto. She had cohabited with a black man commonly, and had received the embraces of a white man on the estate occasionally. Dr. H. Allen did not see the children, both of whom were dead when he arrived in the island; neither can he recollect whether they said they were male or female. But he has no reason whatever to doubt the fact, which is besides remembered by his wife.—N. L."

(Leicester Square, 1784. "Twins born, one black, the other white.")

JOHN HUNTER[1].

I saw a male gold-fish in pursuit of a female carp; therefore very probably they would breed.

I have seen two flies in copulation some hours; they will allow themselves to be drowned before they will separate.

Motion 'in Utero' of Human Fœtus.

The human fœtus has probably more motion in the uterus than that of any other animal: the single circumstance of the greater length of the navel-string would give that idea. But in many fœtuses, if not in all, it would appear that they cannot even turn, the width of the horn of the uterus [in quadrupeds] not admitting of it: this at least is the case with the horns of the uterus of a sow.

The circulation of a fœtus is somewhat similar to that of the Amphibia, a mixture of the two circulations. There is more blood (in

[1] [Hunter would seem to have received the above case, at third hand, from N. L.]

proportion) passing through the liver of a fœtus than through that of the adult: this is also similar to the Amphibia.

Modes of Maternal and Fœtal Communication.

It would seem that the communication between the mother and the fœtus is carried on in two ways, and in the two combined. In the human subject it is entirely by extravasation[1]; in the mare and sow by apposition of vessels; and in the bitch and cat by both ways combined.

When a calf is about half the size of a mouse, the membrane [chorion] on which the cotyledons are placed, passes through the whole horn of the uterus, or lines the whole. Where the embryo is situated the cotyledons are pretty well formed or risen, and as the membrane recedes from this they are fainter and fainter; and towards the two ends they are not observable. The external membrane on which the cotyledons are formed is spongy, and would appear to act like a cotyledon. This [membrane] is lined everywhere by a thin membrane [allantois], which is slightly attached to it: this [allantoic] bag is above half-full of water [serum]. The fœtus lies in a circumscribed bag [amnios] about four times its own size, filled with water, and slightly adhering externally to the inside of the former. The chord goes out and appears to perforate the proper bag [amnios], as also the lining [allantois], and divides into two portions; one runs along the spongy chorion towards one end, the other towards the other end[2].

Of the Situation of the Fœtus and Membranes when there is but one in the two-horned Uterus.

In a sheep that had one lamb in the uterus, it was in one of the horns. I observed two spongy parts in the ovarium of that side, and that the membranes passed into the other horn, and were there attached to the cotyledons as in the same side where the fœtus was[3].

Experiments on Sows.

December 24th, 1781.—In a sow which took the boar on Tuesday and was killed the Thursday sennight following, in the morning, which

[1] [By the maternal blood passing into cavities which have lost the form of vessels, and form the 'sinuses' mentioned at p. 192. See Animal Economy, pp. 60–70.]

[2] [Hunt. Preps. Nos. 3499, 3500, 3501.]

[3] [The experiments on ewes to determine the effects of impregnation on the ovaria, are printed in the Physiological Catalogue, vol. v. p. 120, from a copy of the MS. supplied to me by Mr. Clift, whilst I was engaged in describing the Hunterian preparations, Nos. 3481–3495. The ovarian ovum, of which Hunter appears to have been in quest, being pellucid, colourless, and much more minute than he anticipated, escaped his observation.]

was about ten days after, the glands of the ovarium [ovisacs or Graafian vesicles] were swelled a little, and, when cut into, contained coagulated blood. Some of them contained pieces bigger than a cherry-stone, others were less. The horns of the uterus seemed preparing for the ova, being divided into partitions by a tightness or stricture, but of unequal lengths, some being as long again as others; and those divisions corresponded with the number of glands in one [the ovarium of that] side, being eleven in number; [those of] the other side could not be counted, owing to its being opened later, by which means the parts were not so distinct.

A sow that had taken the boar, April the , was killed April , viz. days after.

[The dates are lost; however, it is not material; it shows the progress and difference in the same animal, some being further advanced than others.—J. H.]

The following appearances were observed:—The ovarium of the right side was larger than that of the left. There appeared several ova [ovisacs] that were more vascular and larger than the others. These were eleven in number, each of which had a part projecting like a nipple, which was more evident in some than in others. The remaining number had this appearance beginning to take place; the other ova [ovisacs] were smaller, of a yellowish white, harder and firmer in consistence. When cut into, they appeared of the same colour [throughout] their whole substance.

One of the eleven [ovisacs] appeared as if it had burst. When cut into, it had an irregular appearance of a cavity, in which there was extravasated coagulated blood. On cutting into the other ova [ovisacs] which seemed impregnated (viz. those which had the projecting appearance), they seemed to be taking on more the appearance of a cavity; which in some of them contained a yellowish serum, in others coagulated blood, but of irregular form, like extravasation into the substance. This was much more in some than in others.

In the other [ovisacs] that had not the above projection, their cavities appeared more circumscribed and perfect; their inner surfaces were very vascular with partial exudations of coagulated blood, and they contained a serum. The left ovarium had seven of the ova [ovisacs] of a red colour, four of which had a projection. One of them seemed ready to burst; and in cutting into its substance, one cavity, whose surface was vascular, was covered with coagulated blood, and contained also serum. The other three were not so much advanced; but all contained coagulated blood, which might be separated from all sides of the cavity[1].

[1] [Here the process of examination seems to have been *sections across*, or *cutting into the substance* of the ovisac, whereby the true ovum was most probably destroyed,

In the uterus of a sow sixteen days gone, the fœtus was formed, and its purse-shaped membrane [chorion and allantois] was above a foot long in some. This membrane, with the fœtus nearly in the middle between each end, occupied nearly the whole length of the cavity of the uterus, like a tape-worm in the intestines. Through the whole course of the uterus was a white mucus almost like cream; and where the fœtus lay, this was most in quantity[1].

In two other sows that were only allowed to go ten days, I could not observe any change whatever, and there was none of the mucus to be found in either uterus.

The connexion between the outer covering of a [fœtal] pig and the uterus appears to be only one of contact; for they separate with as much ease as any two wet substances can do that have no connexion but that of having lain together. Upon close examination, there appears not to be the least violence committed upon separation. The inside of the uterus is thrown into circular rugæ, and so is the external surface of the outer membrane of the fœtus, which appears to confine the membranes in their situation.

There are on the outer surface of the external membrane of the fœtus a vast number of small circular spots, which are rather whiter or paler (from being thicker) than the parts of the same membrane, with a darker centre. These spots do not appear to be more vascular upon injecting, than any other part of the same membrane[2].

In the year 1777 I spayed a young sow of one ovarium only. When she was of age, I gave her the boar, and she brought forth six pigs. The second time she had eight (I slit her ear to know her); the third litter was only six; the fourth litter of ten; the fifth litter, March 1782, she had ten; the sixth litter, September 1782, she had nine pigs. In this instance she had been served with the wild boar; five of the nine were like the father, three like the mother, and one like neither.

The sister of the above sow, although not spayed, did not take the boar so early as the spayed one did. When she did so, I only allowed the boar to serve her once (as was also the case with her spayed sister). This was with a view to see if once was sufficient to impregnate several

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and its contents only observed, which might have been the '*serum*' that Hunter mentions. Had the exterior covering of the mammillary eminence been carefully scratched open, the ovarian ovum might have been detected and removed entire.]

[1] [Hunt. Preps. Nos. 3538–3541.]

[2] [When the veins and arteries are injected with distinct colours, the venous capillaries form plexules in the centre of each of the circular spots. See the Prep. No. 3541 A, presented by Professor Eschricht, of Copenhagen, the discoverer of this arrangement.]

ova, and she brought forth nine pigs, being three more than her sister's first litter. The second time she had only six pigs, being two fewer than her spayed sister. The third time she had eight; the fourth litter, December 1781, was of thirteen pigs; the fifth litter, June 18th, 1782, was of ten pigs; the sixth litter, December 6th, 1782, was of sixteen pigs[1].

Experiment on an Ass.

On Friday, the 2nd of October, 1789, the ass took the male, and I killed her on the Tuesday following, about seven in the morning, making in all what is called four days, but only ninety-two hours. The uterus was immediately taken out, and it was observed that one ovarium was much larger than the other. It was injected on both sides, and by both veins and arteries. When injected, the increased ovarium was much redder than the other, as also was the horn of the uterus on that side. I cut through the small ovarium first, to see if it led to the better exposing of the other which was in a line.

I then slowly divided the other, in which I cut across several small hydatids [ovisacs?], but I came to a glandular substance distinct from the surrounding parts in structure; and, dividing that, along with the other parts, I came to a kind of cavity in which there seemed to be a kind of fine and loose cellular membrane, in the centre of which was a small rounded body, which was a little bag; for in dividing this part, I had cut off a little of the side of the bag, into which hole a small globule of air had entered. Within this was an oblong body, which, when taken out, looked like a little coagulable lymph.

The secondines of a mare and an ass are the same. The urachus in the fœtus of a mare and in that of an ass is a small canal, which passes along the [umbilical] cord, and opens [into the allantois] between the amnios and chorion, which membranes do not adhere anywhere; so that the urine must lie between those two membranes.

"ON THE PROGRESS AND PECULIARITIES OF THE CHICK."[2]

Of the Egg of the Bird.

To understand the progress of incubation, it is necessary we should first understand the anatomy or structure of an egg; and as it is in

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[1] [See Animal Economy, p. 50, for further experiments on the effect of extirpating one ovarium on the number of young produced.]

[2] [This MS. has been printed, with my annotations, in the concluding volume of the 'Physiological Catalogue,' 4to. 1840. The original was not taken possession of by Home, in 1799, and remains in the Archives of the Royal College of Surgeons.]

the Bird we are here describing, it is only necessary to understand the structure of the egg of that order of animals.

The mass of an egg is composed of two parts, the orange-coloured part, called the yolk, and the transparent surrounding part, called the 'white' or 'albumen :' but this term is only applied to its turning white upon coagulation; but as it has all the characters of a mucus called slime, I shall call it the slime. The yolk is a portion of the ovaria, or formed by it; which is what I shall first consider.

The ovarium in the Bird is in one of two states: one is the quiet or [unexcited] state; the other is the state for impregnation. In the first the ova are small, like millet-seed, composed of a little bag filled with a yolk in miniature. They are formed in a cluster in the loins of the Bird, upon the vena cava, as if formed upon it or growing out from it, so as to be inseparable. These small bodies are of different colours in different birds, and sometimes different in the same bird. As the constitution is changing towards propagation, these little bodies begin to swell, by becoming fuller of the matter of the yolk. Some advance faster than the others, in a kind of regular gradation, forming regular series. As they advance they become attached by a neck, which is small and pretty long in some. Their capsule becomes extremely vascular, more especially the veins, which run from the neck as a centre, and spread in a radiated form on the membrane, and then, as it were, converge on the opposite side. When nearly arrived at full size, an oblong part of the capsule becomes very thin, and the yolk can be seen through it. This gives way and it opens, through which the yolk makes its escape. At this very period we must suppose that the mouth of the oviduct is so placed as to catch it, along which it passes.

The yolk is in the centre of the slime, seen through it, as it were swimming in it. It is round, and is lighter, in the whole, in weight than the slime, so that it always rises towards the upper side of the egg; but it is not in equal weight in itself through the whole, one side being lighter than the other, which side always keeps uppermost, let the egg be ever so often turned; like the needle to the pole, let the compass be ever so often turned, the point of the needle keeps to the pole. On this side is the cicatricula, in which the chick is formed; therefore it is always nearest the heat of the mother, although the chick is of more condensed materials, and therefore one would suppose it would destroy this quality on this side of the yolk; yet we find it does not, for this side keeps uppermost till the chick almost fills the whole space or shell, and therefore cannot turn, and now it is not necessary it should. It [the yolk] is of the consistence of thick cream, and is coagulable with heat, solutions of alum, alcohol, goulard, &c.

At each end* of the yolk, towards the long axis of the egg, we may observe a white substance going out, about the size of a white thread, which does not come out at once, but as if its attachment was spread on the yolk, or that it was the membrane of the yolk contracting and sending out the cord. It passes towards the end of the egg, and appears to be increasing in size, more loose in texture, as if gradually dissolving and swelling, and towards its termination it looks like a cloud, or white fumes in the air. These two threads are the axes on which the yolk turns, and keep its lightest side always uppermost. As the most distinct part or terminations of these threads do not turn with the yolk, the thread, or that end which is nearest to the yolk, must twist when the egg is turned; and if the egg is turned oftener in one way than what the threads can twist, then the yolk must turn round with the egg; but as it is not likely this can ever happen in any natural process, no such inconvenience can ever occur.

On one side of the yolk is a lighter spot than any of the other, which is called the 'cicatricula;' in this is the chick formed; but before incubation no traces of the embryo can be discovered, there being no difference between this part that is impregnated, and one not impregnated[1].

The 'slime' is a secretion from the oviduct†, and is collected by the yolk in its passage along this duct, in its way to the shell-forming part, by which means it surrounds this yolk everywhere, but mostly at the two ends, as the egg is of an elliptical form: and here it appears to adhere to the inner membrane more than anywhere else, probably in some measure connected with the two ends above described. It is transparent, having a slight tinge of a yellow in it. Its attraction of cohesion is such, as allows it to have its figure very much altered, and recovering itself somewhat like an elastic body; therefore not a fluid whose parts can be moved on each other, and always keep the place they are moved into. It coagulates into a white substance, which appears to be lamellated.

* I call these 'ends' because they are towards the long axis of the egg.

† Birds have but one oviduct when grown up, although two are originally formed; but it is the left only that remains. In my maiden Preparation[2] there was one on the right side, but it was a kind of dwarf one. This duct is thrown into considerable convolutions (therefore much longer than what was only necessary for a duct), having a meso-oviduct. It may be said to consist of five parts, which are in some degree different in structure. The first may be called the mouth or fimbria, which is an oblique opening looking [like] a slit.

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[1] [This similarity can only be understood as referring to the absence of visible traces of the embryo.]

[2] [Probably No. 2731.]

These two parts [the yolk and white] are enclosed in a pretty large opake membrane, which is lamellated, for it can be divided and subdivided into a number of layers; but it would seem to be divided into two, the innermost the thinner. At the great end this membrane is separated into two laminæ; the outer, or that next to the shell, continues to line the shell; but the inner passes across, leaving a space between the two of about three-eighths of an inch in diameter, and is concave on that side next to the slime; though not so much as the outer one on the side next the shell. This space is filled with air. Over the whole is the shell, composed of calcareous earth, about half a line in thickness, the outer surface of which has a vast number of indentations on it, as it were, looking porous. It appears to have no regular construction; it does not look like crystallization, as in the enamel of the teeth. The colour of the shell in the common fowl is generally white, but in some it is brown, as in the Chittagong fowl. This shell gives the whole a firmness which defends its contents. It certainly admits air to pass both it and the membrane.

The egg, which is the produce of the female, or of the female parts in the hermaphrodite, is to be considered in two lights. In one it is to be considered as the uterus, and in the other as the breast. The slime is the uterine part, intended for the support of the chick while in its uterus or egg; and the yolk supports it for some days after being hatched, in place of milk, although for a much shorter time; so that the oviparous animal collects the whole necessary nourishment, and throws it out at once; while the viviparous retains the rudiments of the young, and furnishes it nourishment as it is wanted.

We have reason to suppose that the slime comes nearest to the nature of blood of any animal substance we know; and we know it is alive, therefore not necessary to undergo any change to have this effect produced; for it is only the absorption of living parts, therefore is capable of composing the animal without having undergone the act of digestion; and in this alone it undergoes but little alteration, as it composes the whole parts without much loss; for an egg, through the whole process of incubation, only loses . . . . grains[1], and as that would produce a vacuum somewhere in the egg,—more especially as the parts formed are more solid than the parts which composed them,—therefore it is reasonable to suppose they would occupy a smaller space. But it would appear that the cavity at the thick end of the egg, between the

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[1] [According to Dr. Prout, the loss of weight in the egg of the common fowl during incubation, exceeds by about eight times that which the egg sustains by ordinary keeping: this latter loss is at the rate of about nine grains daily for a certain period.—Phil. Trans. 1822, p. 377.]

two membranes, was intended as a counterpoise for this loss; for as the chick grows, and of course the whole loses in weight, as also in size, this air-bag swells, by a separation of the two membranes, and fills up the space lost. So that this cavity may be said to be in size, in proportion to the loss and condensation of parts which nourished the chick; and this is one of the purposes answered by it.

As the whole volume of the chick and contents of the egg diminish both in size and weight, it is necessary there should be a provision for the first that the space might be filled: for this there is a provision by means of the air-cell at the thick end, which, in the unincubated egg, is extremely small, but increases as the contents of the egg decrease; and this increase of the air-cell is effected by a separation of the two laminæ of which the lining or internal membrane is composed.

Principles governing the Formation of Animals.

This production of animals out of themselves excites wonder, admiration, and curiosity; and this is commonly the case in effects whose immediate causes are so obscure, more especially when we are ourselves both effects and causes of the same.

The first process set on foot in the formation of an animal is so small, without that form which it afterwards gradually takes on, and its situation so obscure, that its operation cannot be traced but by taking it up at stated times, when we find a new part either added or come to view, or a degree of perfection having taken place in the part.

The larger the animal is in any one order, the more perfectly the parts are seen as they rise to view, and, by this, the intermediate steps in them are more within our view.

If we were capable of following the progress of increase of the number of the parts of the most perfect animal, as they first formed in succession, from the very first to its state of full perfection, we should probably be able to compare it with some one of the incomplete animals themselves, of every order of animals in the Creation, being at no stage different from some of the inferior orders. Or, in other words, if we were to take a series of animals, from the more imperfect to the perfect, we should probably find an imperfect animal, corresponding with some stage of the most perfect[1]. But all our observations

[1] [The same philosophical idea seems to have governed Hunter in penning the following passage: "We may also observe that the first rudiments of every animal are extremely soft, and even the rudiments of the more perfect are similar to the full-grown imperfect, and as they advance in growth they become firmer and firmer in texture."—Croonian Lecture for the year 1782, Animal Economy, p. 268.]

can only begin at a visible stage of formation, prior to which we are left to conjecture, which could only lead us back to still fewer parts; but when the first and necessary parts were first formed, as a basis to put the whole succeeding ones into action, so as to increase themselves and form new parts, is not known, nor can it.

[Magnifying] glasses lead us back far beyond what the naked eye reaches; but these only show us the order of priority in the formation of parts. However, human wisdom can go no further than into the distinction of parts, with their actions and uses when formed.

The mode of the gradual increase of the parts of an animal may be considered in three views; one, where it may be supposed that the basis of every part of an animal is laid at the very beginning, and that its visible perfection is no more than the parts beginning to grow as they are wanted, but that they were there in embryo[1]. Another, where it may be supposed that at first the parts were formed, but were no more in number than just what were wanted for that state of perfection; and as they came to a degree of perfection, new parts were necessary, and they formed, or formed as they were wanted[2]. And the third is, where the parts were there from the beginning, but that they were altered in form, action, &c.[3] So far as my observations go, I think I can see all the three principles introduced, but probably not in the same animal, nor in the same order of animals.

According to the first, I can conceive there are, at the very beginning, parts which continue through life, and such is, probably, the *Materia Vitæ universalis* and the Absorbing System, which may indeed, according to the third principle, be changed. But according to the second, as the embryo is moving towards perfection, new parts are formed; probably first the brain and heart, with their appendages the nerves and vessels, and so on of all the other parts of the body, which we do not find at first. And we know, according to the third [principle], that many parts are changed in form, adapting their use, arising from that formation, to the addition of parts with the changes in the parts, and this pretty universally.

Perhaps the flying-insect is the best example of these observations. This insect has three modes of life, and of course three structures of parts. The structure suitable to the first life [ovum] we know little about, but the difference between the second and third we can examine. In the second life [larva] it appears to have no parts but what are of immediate use for the growth of the animal, and some of them very

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[1] [The theory of 'Evolution.'] [2] [The theory of 'Epigenesis.']
[3] [The theory of 'Metamorphosis.']

different in form from what they are afterwards, while others remain the same: so that in the insect we have, in the second life, parts that were probably of use in the first; we have, at least in the second, parts that are of use in the third, therefore do not change, such as the brain, nerves, and circulation[1]; but in the third life [pupa], we have new parts entirely, and old ones changed. The new parts formed are, the parts of generation[2], legs, wings, &c. &c.; parts changed are, the whole of the digestive powers, in some degree the organs of respiration, and probably the organs of sensation[3]. Thus in the progress of growth, in the more perfect animals, we have new parts arising, changes taking place in those already formed, and old parts lost.

It may be observed, that the more perfect the order of animals is, it comes to a larger size at the first-life than those of an inferior order: thus, a new-born quadruped is nearer to the size of the parents than a bird just hatched, and a bird nearer than a fish, &c. However, there are varieties in this respect in the quadruped, for some have several at a time, which renders them smaller.

From this account we should suppose that a quadruped would be the first for investigation; but as Nature gives to every order of animals a mode of reproduction peculiar to itself, we are led to examine this process in those where its operations are most easily and certainly come at. This must certainly be the case with some of the oviparous, although not with all, and according to the above position the Bird must be the best, and still more so in those that have fewest young in number and largest in themselves.

Without this aid our knowledge of this subject would have been very imperfect, and it would almost appear that this mode of propagation was intended for investigation.

In the investigation of this subject they have commonly had recourse to the common fowl, as being the most familiar; but I found the first appearances so obscure, from want of size in the object, that I had recourse to the progress of the chick in the egg of the goose. I attempted the swan, but it was impossible to procure such numbers as to give me all the necessary varieties. I endeavoured to procure ostrich's eggs, by having them sent to me in spirits; but as the getting such was only a matter of chance, and only one or two in thirty years! nothing could be made out from them. For this purpose, then, I kept

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[1] [These parts can only be said not to be essentially changed, but they are remarkably modified in form.]

[2] [Hunt. Preps. Nos. 3025–3028.]

[3] [See Heroldt, Die Entwickelungs-geschichte der Schmetterlinge, anatomisch und physiologisch bearbeitet, 1815.]

a flock of geese for more than fifteen years, and by depriving them of their first brood in my investigations, they commonly bred again the same season.

As hours make a difference in the first days, it becomes necessary to examine in the night as well as in the day; by which reason, the latter brood in the summer is best adapted, having then short nights.

Of the different Methods to be taken to examine the Progress of the Chick in incubated Eggs.

The first thing necessary is the breaking and removing part of the shell of the egg, which is to be begun at the upper part. In the breaking of the shell of the egg, when the chick is young, as at twelve, twenty-four, or thirty-six hours, it should not be broken where the chick is, that is, not at the very upper part, but a little way from it, and break it round this most prominent part for the breadth of a shilling: this is with a view to avoid the sharp corner of the shell wounding the membrane and hurting the first rudiments of the chick. Then take off the shell, leaving the lining of the egg on; then remove gradually the membrane from over the chick. This must be done with great care and attention; it should be taken off in layers with a pair of forceps. The egg so prepared should be put into warm water as high as the chick, but not allowed to cover it, as water soon kills it. In this way it may be kept alive some hours. It may be necessary to remark, that, while the heart of the chick acts, the blood keeps red; but as soon as it ceases to act, the blood becomes almost immediately pale, and soon loses its red colour; therefore it is necessary to keep the animal alive as long as possible*. When it is examined sufficiently in this state, then, to see the body of the animal still better, the membrane should be cut all round beyond the fœtal circle, and the whole taken off under water; and then have a piece of thin black ivory to slip under it, and put the whole into spirits, which will coagulate the completest formed parts, and bring them to view upon the black ground. In this way I have been able to bring parts distinctly to view that before appeared to be involved in a cloud; also we can bring them under a much larger magnifier, and bring out parts that neither their situation nor glasses could expose.

* Various were my attempts to effect this, but mostly in vain. I conceived that when I had just exposed the little animal by putting it into water, heated to about 204 degrees, just covering the egg, I might keep it alive by these means, and observe in the same chick the whole progress of growth; but it soon died; therefore I was obliged to have recourse to a succession.

When heat is applied to an impregnated egg, the living parts are put into motion, and an expansion of what is called the cicatricula takes place. This very probably begins at the chick as a centre; but it would appear that the whole did not derive its expansion immediately from the chick, for this part would appear to have powers within itself, and the further from the chick these powers are at an early period, the strongest is this expansion of parts; for we find changes taking place in this circle near to the circumference[1], sooner than near to the chick, which afterwards become distinct vessels, and communicate with the mesenteric artery of the chick. The chick begins to take form to itself in the midst of this expansion, and as it increases, its influence is extended into the surrounding parts.

In the beginning of the formation of the chick, there is great distinctness of parts, for they gradually take place one after another.

Of the Membranes of the Chick.

The chick at first, or in its . . . . . . hour, is totally void of membrane, only having over it the external membrane of the yolk[2], which, when removed (which is easily done), the animal is perfectly bare[3].

The first formation or expansion of its membranes are in pretty quick succession, and then go on together, some being sooner completed than others. The first expansion of parts would appear to be the formation of membranes, or changes in membranes naturally belonging to the egg.

The first membrane that is formed is the membrana vitelli[4], which forms immediately under the proper membrane of the yolk; so it would appear that at this time the yolk had two membranes (but how far originally so I do not know), the external, a fine transparent one, and the other, more spongy, and having the power of becoming vascular.

As the parts of the chick begin to form, such as the head and spine, with the medulla spinalis, &c., a proper membrane also begins to form, to cover it. This membrane[5] begins first at the head, and seems to

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[1] [The formation of the *halones* and *blood-lakes* in the area vasculosa is here alluded to.]

[2] [The *membrana vitelli*, or *cuticula vitelli.*]

[3] [In the embryo of the common fowl the amniotic investment begins to be formed at the eighteenth or twentieth hour, but is not completed until the fourth day.]

[4] [The 'blastoderm' or 'germinal membrane,' and not the 'membrana vitelli' of modern embryologists.]

[5] [The 'serous layer' of the germinal membrane: it is also called the 'animal layer' by some embryologists; but that the serous layer is the covering, and not the

arise from the membrane round the head; and, as it increases, it gradually covers the upper or exposed surface of the head, like a hood; then gradually extends itself along the body, covering more and more of it towards the tail, having always a determined edge: and when got to the tail, it there closes up the animal entirely, on the upper side, and which has only the membrana vitelli upon it, making a circumscribed cavity, in which the chick lies, and which I call the 'amnios,' as being the immediate covering of the chick, composing a part of the secondines or after-birth.

This membrana vitelli [germinal membrane] would appear to have formed itself from the intestine; if so, then it was prior to that part being visible; or it might be considered an expansion of, or a process from, the intestine over the yolk, and under its own proper membrane. That part next to the chick appears to divide into several laminæ, or has the power of forming several; for we find, by the time the whole has formed such and such parts, that we can separate it into . . . . . laminæ, which are seen in Plate ——, figs. ——[1]. This membrane is extending itself over the yolk, expanding itself till its edges come beyond the largest diameter, and now, as it expands in length from the chick, it contracts at its edge, and at last encloses the whole yolk, forming on the opposite side something like a cicatrix, to which the last part of the slime adheres.

From this account of the yolk, and this membrane, it might appear that this membrane was only at first a covering communicating with the belly of the chick, preparatory to, or for the entrance of the yolk into the abdomen just before hatching. But from its structure it would appear to have some use while under incubation, for it first becomes extremely vascular, and on its inside it is thrown into rugæ[2], as if an increase of inner surface was necessary: wherever this membrane advances, the yolk becomes fluid, beginning at first where the mem-

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framer or framework of the organs of the animal functions of the chick, seems evident from its extending beyond those parts, over the yolk, to form the false amnios; it only forms the cuticle and the amnios of the embryo itself. It is because the membrane is folded over the substance of the medulla spinalis and vertebræ, as these are formed, that it has been said to form them. It was first described by Pander, in his masterly Thesis entitled "Dissertatio sistens historiam metamorphoseos, quam ovum incubatum prioribus quinque diebus subit." 8vo. 1817.]

[1] [See Physiological Catalogue, 4to. vol. v. fig. 7. plate 69, fig. 5. plate 70, and the beautiful magnified view of the chick resting upon the yolk, in plate 71, where *b*, the serous layer, is reflected from *d*, the vascular layer and mucous layers of the germinal membrane, or 'membrana vitelli' of Hunter. See also the mucous layer, *f*, fig. 5, plate 75, reflected from *g*, the vascular layer of the germinal membrane or vitelline sac, in a further-developed embryo.]

[2] ['Vasa lutea' of Haller.]

brane forms, extending itself as the membrane of the yolk extends, by which means the yolk is rendered fit for passing through the duct into the intestine, after the chick is hatched; and it is even not coagulable with heat, so that we may know when an egg has been sat upon, when boiled, for the yolk remains a thin and watery fluid.

As the chick grows, it presses down the middle of the yolk, first making a deep indent in it; and as it increases in length this indent is increased into a groove, which becomes deeper; and by the time the chick is at its full growth, the yolk is almost divided into two portions, between which lies the chick.

When the chick is so far advanced as to have most of its parts begun to form, such as the extremities, which is about the . . . . . hour[1], then begins to form the *third* membrane, in form of a circumscribed bag, which seems to come out from the belly near the anus, full of water[2]. This, by increasing, spreads upon the chick, or over the above membrane, and covers them, and as it increases, it covers the whole albumen that remains; and, as the slime diminishes, it becomes also a covering for the yolk; so the chick, albumen and yolk, are at last enclosed by means of this bag; but as it is a circumscribed bag in itself, these parts are on the outside of its cavity; but, by its forming a circumscribed bag, in its double capacity it may be said to form two circumscribed cavities; and it is therefore to be understood that the chick is only enclosed between this bag and the membrane of the yolk, and is therefore not *within* its proper cavity, but upon its outside.

This cavity, originally arising from the rectum, communicates with it by a small duct, and probably is formed upon it, through which passes the urine; whence this cavity should be called 'allantois,' although the membrane that forms the cavity has various uses; it absorbs the slime as it covers it, and therefore should be called placenta: it comes in contact with the shell, and acts as lungs*.

The urine in the chick is similar to that of the adult, a white slimy substance; that which is in the allantois is firmer in texture, appearing like strings of coagulated white of an egg, when thrown loose into hot water. The water which it contained at first appears to be absorbed, for none is found towards the last stages of incubation.

* In animals that have [a urinary] bladder, this duct forms itself into that cavity. In the crocodile the bladder opens into the gut, but in the quadruped the urachus opens into or forms a passage for itself, called urethra.

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[1] [In the embryo of the common fowl the extremities begin to bud about the 60th hour.]

[2] [See Physiological Catalogue, 4to. vol. v. plate 71 *f*.]

Where the allantois covers the chick it adheres to the amnios, making but one thin membrane between them, but it never becomes attached to the membrana lutei or vitelli[1]. As it extends, it would appear to push from the chick the remaining slime towards the opposite side to that of the chick, as it were clearing the yolk of it more and more, so that the slime becomes smaller, and at last lies like an oblong body close and adhering to the cicatrix of the yolk. So far as these membranes are attached to the membranes of the yolk, they would appear to detach themselves from it by the time it is ready to be absorbed into the cavity of the abdomen; for none of the other membranes are taken in with it, and it has no other attachment to the abdomen in any of this class of animals.

Of the Use of those Membranes as they arise.

The formation of the chick seems to be but little prior to the formation of the membrana vitelli [germinal membrane], if at all prior; for among the first appearances is a spreading of the cicatricula, and the centre would appear to contain a fluid. That the formation of the chick is considerably prior to the formation of the other membranes is evident; therefore it might be asked, how the chick is nourished, and other functions carried on, till those other membranes are formed? supposing that they absorb the slime. But the membrana lutei [germinal membrane] performs this office, at least at this time, and there was a certain space of the membrana vitelli [germinal membrane] that had the powers of forming vessels and red blood, and which became very vascular. This membrane would appear to answer two purposes, one for the purpose of the chick, another as a covering to conduct the whole yolk into the abdomen.

That the membrane which I have called allantois, from its containing urine, answers other important purposes, must appear evident from its extent being far beyond what would answer that purpose. I conceive that the side of this bag, which surrounds and is in contact with the albumen, acts as the chorion or placenta, for it must be by this surface that the albumen is absorbed, and the chick supported. The external part of this bag, which comes in contact with the shell, and as it enlarges lines more and more of it, till at last it lines it everywhere, I conceive to be the lungs, for it is the only part that comes in contact with the air; and on opening an egg pretty far gone, I find that the blood in the veins is scarlet, while it is of the modena colour in the

[1] [Vitellicle, or vitelline portion of the germinal membrane.]

arteries of the bag. Besides, it is much more vascular than any of the other membranes, which is just the reverse of what we should imagine, if it did not answer that purpose[1].

Of the Formation of the Parts of the Chick.

As the parts which act in both stages differ very considerably in their structure, the structure of the first not being adapted to the economy of the second, we have an opportunity of investigating those changes which may be said to give us the gradual formation of parts till completed. The heart is the only visible acting part, and the construction of that viscus in the very young is not similar to that of the full-formed. From hence we can have its formation through its various changes.

The first parts that are visibly formed may be said to be the brain and spinal marrow, although we may conceive the heart and vascular system is also formed, suited to such a state, and that it is co-existing, but not seen, because transparent, while the brain, &c. is opake, and can be rendered much more so; by which means it becomes still more evident; for if the brain, &c. was transparent, the heart would be the first visible object from its motion, and afterwards [from its] becoming reddish.

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[1] [The vascularity of the external fold of the allantois, the porosity of the shell, and the difference in the colour of the blood passing from the chick to the allantois, to that returning from the allantois to the chick, give the highest probability to the opinion expressed in the text of the respiratory function of the allantois, and of the necessity of access of air to that membrane through the pores of the shell, for the development of the chick.

The experiments by Erman, commenced in 1810, and published in the 'Isis' of Oken for 1818, were performed with an apparatus by which the requisite heat could be applied to a fertile egg in a presumed vacuum, or in an atmosphere of artificial gas; but the apparatus being defective in regard to the luting used to cement the bell-glass to the brass-plate employed, Erman's arguments, that oxygen was not necessary to incubation, are inconclusive.

His experiments, repeated by Viborg, with the substitution of a more effectual luting, were followed by the opposite result. Oxygen was found to be essential to development, and atmospheric pressure, afforded by the medium of other gases, as hydrogen and carbonic acid, was followed by no appreciable change in the cicatricula subject to the incubating temperature.

The requisite pains and precautions, which the present advanced condition of chemical science enables the experimenter to put in practice, appear to have been effectually taken by Dr. Schwann, who has made the question, "De Necessitate Aëris Atmospherici ad evolutionem Pulli in Ovo incubito," the subject of a most able and valuable inaugural thesis, published at Berlin in 1834. From which it appears that the development of the embryo in the common fowl may go on without oxygen in the ordinary course to the fifteenth hour, and that the life of the germ is not destroyed till between the twenty-fourth and thirtieth hour, but that the presence of oxygen is essential to further development.]

The animal would appear to begin at the back, as it contains the spinal marrow, in which is to be included the head, as it contains the brain, and it seems to build forwards, and the new parts are formed in succession; so there appears to be originally no outline of the whole, and the parts to form in it; therefore every part is formed on the outside of the animal: thus we see the heart, then the lungs, the intestines, and over the whole the skin of the abdomen, which is not perfected till the animal is ready to hatch, and sometimes not even then.

As this only relates to the bird, it may be supposed to belong to it only; but there is reason to believe it is the same in other animals; for in some monsters, in the quadruped, we have no abdominal parietes, only the bowels covered by a thin skin, which leads us to conjecture it possible that they also are formed without any abdominal parietes. This state of deficiency of the parietes of the abdomen has all its degrees, some much more, others less.

The chick is formed first on its back, and then turns on its left side; and till this period the heart is not seen, or if it exists it must lie before the medulla, which will, from its transparency, render it obscure; for in this side view, we see, as it were, the profile, and from its lying in a transparent fluid, it can be seen moving in it even before there is any red blood[1].

Of the Blood's Motion in the Chick.

The circulation of the blood in the fœtus of the common viviparous animals may be divided into two parts: the first is that which passes immediately through both sides of the heart with the connexion between the arteries of the right and left side of the heart. The second is that which is connected with the membranes for the fœtus's nourishment.

In the oviparous animals the motion of the blood may be divided into three; first, as above, for instance, its motion immediately through the heart, and the communication between the arteries of the right and left side; the second, as above, viz. the connexion with the membranes for nourishment; and the third (which is probably peculiar to them) is the

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[1] ["The red globules appear not to be a natural part of the blood, but, as it were, composed out of it, or composed in it, and not with it; for they seem to be formed later in life than the other two constituents; for we see while the chick is in the egg the heart beating, and it then contains a transparent fluid before any red globules are formed, which fluid we may suppose to be the serum and lymph. Whatever may be their utility in the machine, the red globules certainly are not of such universal use as the coagulating lymph, since they are not to be found in all animals, nor so early in those that have them."—Hunter, On the Blood and Inflammation, 4to. 1794, pp. 45, 46.]

circulation into the membranes for the influence of air, which membranes may be called the fœtal lungs.

The vessels of the chick are different from the human, more like [those of] the puppy or kitten, although different from them in some of their vessels. The motion of the blood in the chick, in and through the heart, is not different from [that in] the quadruped; that is, the communication between the right side and the left is the same, having a foramen ovale, but the communication between the two arteries is a little different, having two 'canales arteriosi' instead of one.

Of the peculiar Arteries of the Chick.

These arteries are three; the two first, or what may be called a pair, and which answer to the umbilical arteries in the quadruped, arise from the iliacs, and pass by the sides of the bones of the pelvis towards the opening of the abdomen, and when got out of that cavity through this opening, ramify on the three membranes above described. The third[1] is a continuation of the mesenteric artery, and is principally lost on the membrana lutei.

Of the Veins.

There are two venæ umbilicales; one (which is the largest) belongs to the amnios, chorion and lungs[2], and is similar in its termination to the umbilical vein in the quadruped, the trunk of which passes into the abdomen, then upwards to the liver, enters between its lobes, and opens into the vena cava inferior, just as it enters the heart. The other[3] belongs to the membrana lutei, and passes into the abdomen, joins the mesenteric vein, which would appear to divide into two, one forming the vena portarum, the other joins the vena cava inferior between the kidneys, and which communication remains through life.

In the diastole of the auricles more blood passes into the right than what it can contain, and the overplus passes, as it were, through the right auricle into the left, while at the same time the left is receiving blood from the lungs, so that the left is filled partly from the body, therefore they are equally filled with blood. But the quantity from the lungs is increasing every day in proportion as the lungs increase, for the lungs can hardly be said to be coeval with the heart.

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1 [Vitelline or omphalo-mesenteric artery.]
2 [By 'chorion and lungs' Hunter intends the 'allantois.']
3 [Vitelline or omphalo-mesenteric vein.]

Of the Brain and Spinal Marrow.

It would appear, upon [examining] the most early of these parts, that they were originally formed in two distinct parts, a right and a left; at least there is a transparent line which runs through their whole length, dividing them to appearance into two; but these parts are too small and too tender to allow of ascertaining this as a certain fact; and indeed this division takes place in some degree in parts in the adult; for we find the cerebrum and cerebellum divided into two, as also the medulla spinalis nearly divided into two, longitudinally. The union in the brain of the chick seems to take place soonest about the basis of the brain, making the anterior end appear as if slit into two, like a pair of pincers.

Of the Formation of the Intestines, &c.

The intestines, and probably the liver, spleen, kidneys[1], &c., are the latest formed; yet the principle upon which they are formed must be begun early, for the mouth is early formed, as also we may suppose the anus, for the bag described as above [allantois] arises from it; therefore there is only the intermediate canal to form, and its communication with the yolk; but as all those parts are only fitted for the second stage of life, it was only necessary they should be perfected by that time. The small intestines which join the yolk are drawn further out of the belly as the chick grows, but before the chick hatches they are gradually pulled in[2].

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[1] [The kidneys begin to be formed in the chick on the sixth day, and in the tadpole as it is passing from the embryo to the larva state. But there are excretory organs prior to the kidneys, called from their discoverer the 'corpora Wolffiana,' consisting of hollow cæca attached to an excretory duct, and developed in birds on the third day, which secrete a yellowish urine; so that the allantois may contain urine from the first period of its existence. The corpora Wolffiana disappear in birds at the time of exclusion, in Batrachia at the latter period of the larval state, in Mammalia earlier, and in Man soonest of all. See Müller, Bildungsgeschichte des Genitalien, Dusseldorf, 1830.]

[2] [The observations of Wolff on the development of the digestive organs of the chick, published in 1774, are more numerous and precise than those of Hunter. Of the formation of the glands Hunter says nothing. Malpighi seems to have been the first who recognized the primitive form of the liver. '*Septimâ* terminatâ die'—'Jecur ipsum, subluteo interdum suffusum colore, quandoque cinereo, auctius et solidius reddebatur, et ipsius glandulæ non omnino rotundam et sphæricam referebant figuram, sed oblongiores et quasi *cæcales utriculos*, ductui hepatico appensos, repræsentabant.'—Epist. de Formatione Pulli, p. 9. *Op. Om.* fol. 1687.

Von Baer and Müller perceived the first development of the liver in the chick at the middle of the third day; it then appeared as two pyramidal hollow cæca developed from the duodenum.]

The parietes of the abdomen are the latest in being formed, and when that is effected the animal is completed; but this is much later in some of the oviparous animals than in the quadruped, and the lateness of forming this part is owing to the yolk's being taken into the cavity of the belly at or near hatching; and to effect this purpose we find that from the circumference all round the opening into the belly arises a muscular expansion which enters the yolk (besides its proper membrane), surrounding the whole, which by its contraction draws the yolk towards the opening, and then by its contraction that part of the yolk which is close upon the mouth of the opening is shoved into the belly; and by this action some of the yolk (which is become fluid) is squeezed into the intestine, which by regurgitation in that canal is carried up into the stomach, and is there first coagulated to be afterwards digested.

As birds have air-bags within the abdomen, I find that at a certain period of growth of the chick they begin to form. They begin at the lower point of the lungs like a small hydatid, and extend further and further into the abdomen, before and on the outside of the kidneys: they are at first full of a fluid; as they extend, they are, as it were, squeezed among the intestines, so as to take on the shape of the intestines of those parts, and at last filling the whole abdomen among them. Soon after others are forming, or other openings communicating with this, and the lungs are also beginning to attach themselves so as to form a communication with other parts, as the ribs, sternum, vertebræ, &c.

The lungs are, at first, detached bodies, as in the quadruped, but when arrived about the third week (in the goose) they begin to be attached to the ribs, but not so early to the diaphragm.

Among the latest formed parts of the chick are the eyelids. When gone through one half of their period of incubation, the whole anterior surface of the eye is exposed, and the termination of the common integuments is perfectly round, as in fig. [12. plate 76, *tom. cit.*] But in a day or two more it begins to form itself into an oblong opening, as in fig. [16. plate 76, *tom. cit.*], which becomes narrower, as in fig. [5. plate 75, *tom. cit.*], and then the increase of lid becomes more remarkable in the lower lid, becoming first almost straight, as in fig. [17. plate 76, *tom. cit.*], which afterwards becomes rounded on its edge, almost covering the whole of the lower part of the eye, as in fig. [18. plate 76, *tom. cit.*], and about a day or two before they are hatched the lower lid has spread upwards so much as almost to cover the whole eye, as in fig. [plate 78, *tom. cit.*]

The membrana nictitans begins earlier to form than the eyelids, for in fig. [16. plate 76, *tom. cit.*] it is seen at *a*, and its increase may be observed in all the other eyes at letter *a*.

It may also be observed, that at no period could I observe a membrana pupillaris.

The little horny knob[1] at the end of the beak with which it breaks the shell when arrived at the full time and makes its escape, is also gradually forming into a more regular and determined point, the progress of which is seen from the first figure to the sixth.

When very young we may observe *two* oviducts, one on each side; they would appear to be behind the kidneys at their first formation, but become more and more forwards as the chick grows, and before hatching the right seems to decay.

There are two kinds of down on the chick, one long, which comes first, about two or three days before hatching; a second, or fine down, forms at the roots of the other. It is probably the long down that comes off with the feather.

The chick some time before birth has a kind of mixed action of life, for it breathes, and we can hear it pip and chirp in the egg; and we find that the adult circulation through and out of the heart is formed before birth: yet it is receiving its nourishment from the remaining slime.

Vivification of the Embryo.

For this purpose a heat is always necessary equal to the heat of the parent animal. In the human female and in the hen, the heat of the body [is higher than that of the surrounding atmosphere, and therefore in the one, vivification goes on in the uterus, in the other, under the belly of the parent. But in] the turtle, fish, &c., where the heat of the animal [is the same as the atmosphere, the ova are left to incubate at a distance from the parent].

Where the natural heat of the animal is the same with, or very nearly that of the atmosphere, the parent is not solicitous about its ova, as, for example, in fishes, in the turtle [*Chelone*], [in many] insects, &c.

Generation of the Eel[2].

The natural history of the mode of propagation in the common eel [*Anguilla latirostris*, Yarrell] has, I believe, never yet been described; and this has probably in some degree arisen from a dissimilarity between their [generative] parts and [those of] fish in common, so as not to enable one to reason from analogy; and, as the mode of propagation in animals can only be known when that operation is going on

[1] [Physiological Catalogue, vol. v. plate 76, figs. 17, 18 *b*. Hunt. Preps. Nos. 3457, 3459.]

[2] [Hunt. Preps. Nos. 2660 (*Conger vulgaris*), 3202 (*Anguilla latirostris*).]

in them, and [by] following it through most of its stages, it has lain almost unintelligible in the eel from the difficulty of finding them in this state. It was not even known whether they were oviparous or viviparous, and from this state of ignorance Sir John Hill[1] has declared them viviparous; probably from conceiving it [to be the] most probable [mode], as their mode of propagation was so obscure as not then to have been discovered.

In my pursuits in comparative anatomy, especially [as to] the mode of propagation in fishes, the eel was not forgotten; and, as I found in this fish parts situated similar to the roes in other fishes, although not similar in the immediate appearance for propagation, yet being such as demanded attention, [this] therefore made me more desirous of knowing both the mode of propagation and the use of these parts in case they might not be intended for such purposes.

That I might be able to ascertain these facts, I got eels every month in the year from the fishmonger with a view to catch them in the breeding season, as also of every size, but I never could distinguish any difference in these parts in any of the months. However, I was told that this was not a fair trial, the fishmongers often keeping them for months in their troughs, in which time we cannot suppose they are going on with this [the generative] process; and to get eels from the river regularly was not an easy matter.

The part which I suspected to be the ovarium, when viewed with a magnifier, appeared a little granulated like some fatty membranes; and there being in some of the amphibia, as the lizard, frog, &c., regularly formed bodies composed of fat, I boiled this part to see if any oil could be extracted; but it boiled away to a pulp without yielding any[2]. Having failed in all my examinations on this part of the common eel, and being in the island of Belleisle in the summer of 1761, where there was a vast number of conger eels, I dissected some of them for their anatomy, and observed they had the same parts with the common eel which I had supposed to be the ovarium or roe[3].

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[1] [The pretensions of this writer to a scientific character are shown in the 'Correspondence of Linnæus,' published by Sir J. E. Smith, P.L.S., 8vo. 2 vols. 1821. Sir John Hill was patronized by Lord Bute, and among other works, including a satire on the Royal Society, he compiled a 'Natural History of Animals,' fol. 1752–1773.]

[2] [If the fat-like fringe on the sides of the air-bladder and kidneys of the eel or conger be examined during spring with a common pocket lens, or later, to about September, without the aid of a glass, the ova may be seen gradually acquiring their full size; in estuary eels taken in October and November, the ovaria are shrivelled and empty. The shotten congers are procurable early in September, and are then usually much darker than at other seasons.]

[3] [Hunt. Prep. No. 2660.]

I then opened many to see if I could discover any spawn, but never succeeded.

As the lamprey and the lampern have, in some degree, a similarity to the common eel, and as their seasons of propagation are known, I next examined them with the same view when full of spawn, and easily found their parts for propagation[1], which are somewhat similar to those parts in the common eel, as I had suspected; and, although not exactly so, yet sufficiently to show the analogy.

So far encouraged I did not give up the pursuit in the common eel, and was still further encouraged by Sir Joseph Banks, mentioning that when young, he had observed in an eel the roe full of eggs or spawn; but as he was then not well acquainted with the anatomy of this fish, and only knew there was an uncertainty respecting the mode of propagation, he therefore only preserved a part, and put it into spirit for further examination; but the spirit evaporating, it dried and was rendered unfit for investigation. Sir Joseph giving me leave to look at some sea-eels caught when on his voyage round the world, in them I found the roe full of eggs, and have since compared them with the common eel, in which I have at last discovered the mode of propagation, which is exactly what I suspected from the structure of the parts.

On the present occasion it may not be improper to give a short description of the roe in the common roe-fish, with a view to show the difference [between them and the eel] which probably was the cause of its [the mode of propagation in the eel] not being before discovered.

The roe in fishes in common, or what may be called the 'roed-fish,' consists of two bags; in some these are long, extending nearly through the whole belly of the animal[2]; in others they are round[3], &c. They are smooth on the outside; and on the inside are thrown into a number of flakes or folds, increasing the surface greatly for the form and attachment of the eggs or spawn.

These bags terminate each in a duct near the anus, which ducts join each other, forming one, which enters the anus near the verge, through which the ova pass.

In both the lamprey and lampern the roes are not bags having the ova attached to the folds on their inside, as in the above described, but are composed of flakes or layers attached at one base along the back, having no cavity. Each flake is composed of two membranes united by cellular membrane, and on the inside of each membrane are the ova as

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[1] [Hunt. Preps. Nos. 2658, 2659, 3196–3201.]

[2] [Ib. Nos. 2663 (Barbel), 2668 (Mackerel).]

[3] [Ib. Nos. 2673 (*Cottus Scorpius*), 2674 (Wolf-fish, *Anarrhicas*).]

close together as they can well be placed; and they may be seen externally through the membrane composing the flake. When these fishes have spawned the flakes become flaccid, but still the nidi may be seen in little opaque spots. The mode of spawning I shall describe in the common eel.

In the common eel, and also in the conger, the roe is somewhat similar to the above, although not exactly. Each roe is composed of a membrane attached by one edge to the back of the fish, almost through the whole length of the abdomen, and continued into the tail some way beyond the anus: the other edge is unattached, and is longer than the attached one, so that it hangs like a ruffle[1]. On the sides of this membrane are a number of folds, similar to the inside of roes in common; it is similar to half of a common roe slit up through its whole length, having the smooth membrane on one side and the flakes or folds on the other.

These roes in the lampern, lamprey, conger and common eel, have no duct or outlet directly belonging to them; therefore the operation of spawning is uncommon, and probably peculiar to this order of fish. The passage out appears to be by two openings, directly from the cavity of the belly just behind the rectum, which unites into one, and opens into the rectum on the further side of that gut just at the verge of the anus*. From this formation of parts, the question is, how do they spawn? In the common fishes the parts themselves explain this operation, and in the present we must have recourse to the same method.

In the common fish we must suppose that the ova fall off and get loose into the cavity of the roe or ovarium, and then are protruded out of that cavity through the duct, by the action probably of both the roe and of the abdominal muscles, which forces them externally.

In the eel, &c., we must suppose them [the ova, to be] forced out at the small opening above mentioned by the same kind of action.

From the structure of the parts, this method of accounting for the operation of spawning appears to be the only possible one; and although it may be difficult to conceive how the spawn, when loose in

* All of the ray-kind have two openings from the belly, one on each side, by the fin at the anus[2].

[1] [This mode of attachment of the ova to fringes, as compared with the compact masses of the ovaria in other fishes, is admirably adapted to the vermicular winding motions of the eel.]

[2] [In the Hunterian preparation of the salmon, No. 2662, the peritoneal apertures are shown, within the verge of the vent, between the cloacal apertures of the bladder and rectum; as described in my Physiological Catalogue, 4to. vol. iv. p. 130. The proper oviducts are wanting in the salmon-tribe, and the ova are excluded by the peritoneal outlets, as in the eel-tribe.]

the cavity of the abdomen, should all be brought to these small openings, and there make their exit, yet it may not be the less true; and that this is the most probable way, is still strengthened by [my] having seen the eggs in the lampern [*Petromyzon fluviatilis*], whose structure is the same [as in the eel], loose in the cavity of the abdomen, in their season for spawning, and other eggs that were not detached, upon the least handling dropped off from the ovaria.

This structure, although in some respects appearing calculated for the formation of the spawn, yet as that spawn had not been seen and as there was no visible outlet for the spawn when detached belonging to these parts themselves, as is in other fish, it was no wonder that in some minds it remained a doubt whether they were the parts or not. This of having no outlet belonging to the parts themselves is a curious fact[1].

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[1] [It appears that eels, as a general rule, do not breed in fresh water, but that there are regular migrations of those with milts or roes enlarging, from inland waters to the sea or to the estuaries of rivers, at the end of summer; and of 'elvers' or young eels, from those situations to the fresh waters in spring. These, having passed gradually from the brackish or salt to fresh water, ascend streams and drains and spread themselves through the inland waters. The eels descend the river Yarrow to spawn in the end of September. The 'elvers' ascend the river Connor about the 20th of May, in a slender column about two feet wide, along the edge of the stream. They creep up the wet posts of sluices, and sometimes twist themselves into round balls about four inches in diameter, with their heads turned outward. Mr. Yarrell states that "the passage of the young eels up the Thames at Kingston, in the year 1832, commenced on the 30th of April and lasted till the 4th of May. It was calculated, by two observers of their progress in that year, that from sixteen to eighteen hundred passed a given point in the space of one minute of time." —British Fishes, vol. ii. p. 291. Mr. Yarrell's observations on the oviparous generation of eels, are given in the second series of Mr. Jesse's 'Gleanings in Natural History,' 8vo. 1836.

A correspondent of Loudon's Magazine of Natural History thus narrates, as an eye-witness, some of the phenomena of the generation of the lamprey:—"On the 8th of May I observed a number of lampreys in the act of spawning; and, remembering the queries of your correspondent, I stood to watch their motions. I observed one twist its tail round another, and they both stirred up the sand and small gravel from the bottom in such a way as convinced me it was a conjunction of the sexes: each sexual conjunction was followed by the ejection of a jet of eggs from the female. I caught them both and dissected them: the sexual organ in the male was projected above a quarter of an inch, and the body filled with milt; the female, though she seemed to have already shed a considerable quantity of her spawn, had still a tolerable stock remaining."—Vol. v. p. 745.

Lampreys drag out stones from the bed of their river by their suctorial mouths, and oviposit in the cavities thus left: the *Petromyzon marinus* spawn in pairs, the *Petromyzon fluviatilis* act in concert, forming a common spawning-bed.

Cuvier repeats the current belief of the hermaphroditism of both the eel and lamprey, and appears to consider the occurrence of a single male lamprey, as noticed by Majendie and Desmoulins, to be an accidental or anomalous circumstance. See the Histoire des Poissons, 4to. vol. i.]

On the Oviparous Water-snail [*Limnea stagnalis*].

This water-snail spawns its spawn enclosed in a fine jelly, perhaps about fifty [eggs] at a time. The egg when taken out of the jelly is a round body, a little flattened and a little oval; it has a pretty strong coat. When burst, a transparent jelly comes out: there is no yolk[1]. In a few days after the spawning, the small shell is seen forming in this little body like a white spot, which increases till it occupies the whole. When those little spots, or snails, are only about the 100dth part of the size of the whole, we see them moving in the egg[2]. The question is, how are they nourished? Do they drink the contents? have they any connexion by way of absorption? In about three weeks they begin to hatch and come out of their shells. The slime in which the ova are enclosed does not coagulate in spirit.

On the Viviparous Water-snail [*Paludina vivipara*].

In the middle of July they appear to be completely pregnant, the uterus full of young in all their stages[3], from the gelatinous ovum or embryo to the complete snail, with its shell formed and capable of moving about with ease. The number in one snail about fifty or sixty.

Generation of the Mussel [*Anodon cygneus*].

In the beginning of July these appear very fleshy and [their soft parts] fill the shell. The outer membrane [mantle] appears granulated, and much like the ovarium of several fishes. This granulated appearance is also seen on that fleshy mass [ovarium or testis, with the liver], in which the intestine takes its turns. These [granulations or ova] seem in prodigious numbers; and sometimes I have seen these ova becoming of a darker colour, but not so as to be clear that they were young mussels.

The mussel, as well as most other animals, is subject to animals living upon it. They seem like a beetle in shape, and are about the size of a large pin's head, with a large body, long legs jointed, and

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[1] [No 'food-yolk' appended to the 'germ-yolk.']

[2] [The rotation of the germ-yolk and embryo on its axis is produced by the action of vibratile cilia on the surrounding albumen. The development of the *Limnea* is well described by Pfeiffer in his 'Naturgeschichte deutscher Land- und Süsswasser-Mollusken,' 4to. 1825. See also my 'Lectures on Invertebrata,' 8vo. 1855, p. 569. Hunt. Prep. No. 2313.]

[3] [Hunt. Preps. Nos. 2942, 2943.]

armed with spikes like a crab[1]. These breed by laying their eggs round that opening where the excrements are discharged, and where the water is drawn into the gills, and are there hatched, about fifty or sixty in number. They may be pinched off, being about the size of small pins' heads; and by viewing them with a microscope, they may be distinctly seen in their different stages, from the ovum to the complete animal (preparations of them in their attachment and adult form). [Quære: Where?—Wm. Clift.]

Generation of the Oyster [*Ostrea edulis*].

The mode of generation in the oyster, mussel, &c., has not been in the least known, which has been from the want of appearance of parts of generation [in them]. But I have taken notice in the oyster that there is a great difference of appearance in the animal at different times of the year. In the winter they appear full or fleshy, by a thick white soft glandular part covering the stomach, liver, and intestines. This part seems to be made up of vessels branching like veins over the liver, and those branches open by two small orifices into that passage leading to the inside of the gill, on each side of that projecting part made by a doubling of the intestine; and at these openings the contents may be squeezed out, which in the winter contain a milky fluid, or rather like cream, but not so high-coloured; and at this time, when viewed in a microscope, [the contents] appear of a uniform texture. But in June I observed that they were becoming smaller, that is to say, the gland was decreasing. I squeezed the matter out, observing that it was more viscid; and on diluting it with water, and viewing it with a microscope, there evidently appeared small ova in it, pretty well determined [in shape] and nearly equal [to one another] in size.

This happened to be in the beginning of July, and now they [the oysters] were becoming very thin. On opening one, I observed a purplish granulated appearance like very fine sand in the gills, [with] in the shell; and on viewing it in the microscope, they appeared to be oysters formed with their shell, and by their transparency I could see the embryo of the oyster; but I never could get them so far advanced in the ovarium.

After this, at the Isle of Wight, I found several where the ovarium was decreasing; and on squeezing out the contents, I observed the ova more distinctly than I had ever [before] seen them.

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[1] [*Acanthoscelis*, 'Lectures on Invertebrate Animals,' p. 525. The true embryo of *Anodon* has a hooked apex and spines on the shell, and was supposed to be a parasite by Rathke, who described it under the name of *Glochidium*.]

ON THE GENERATION OF INSECTS.

Of the Parts of Generation.

Insects cannot be said to have external parts of generation; for, although the penis in the male can be made to project, yet in its accustomed situation it is in the abdomen.

The females have no external parts, excepting the opening of the vagina, which is hid by the two last scales[1]. The opening of the anus in the beetle is, I believe, in the same horny apparatus with the vagina.

Male Parts of a large Moth.

At the termination of the back is a strong horny hook that bends downwards, in the curve of which opens the anus. There are two lateral, but smaller hooks. The penis is a horny body which comes out under the anus, and has a spongy 'glans.' It moves backwards and inwards in a horny groove or ring, which is fixed in a pretty large horny apparatus.

In a large green grasshopper [*Acrida* (*Phasgoneura*) *viridissima*] with hardly any wings and with a long tail [ovipositor], which divides the anus from the vagina, I found a bag between the rectum and vagina whose opening was just at the verge of the vagina, which I suppose is the 'depository of the semen'[2].

Male Parts of the Rose-beetle [*Cetonia aurata*].

The male parts consist of a penis, testes, and other glandular ducts. They are all contained within the abdomen in their natural state or position, but the penis may be made to project[3]. Within the two last scales of the abdomen there is a horny apparatus for the projecting muscles of the penis to act from, which may be called their pelvis. The penis is large, composed of a horny substance, flat upon the upper and lower surface from edge to edge; it is a little bent, the hollow of which curve is on the under surface, so as to be better adapted to enter the vagina of the female, which is underneath[4]. Through the centre of this

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[1] [The female *Lepidoptera* possess two sexual orifices, one behind the other, of which the hindmost serves for oviposition, the foremost receives the male organ *in coitu*.]

[2] [It is the 'spermatheca' (Hunt. Prep. No. 3168), and is the homologue of the "bag" in the silk-moth, which Hunter experimentally proved to contain the semen of the male. See Animal Economy, p. 461. Also my 'Lectures on Invertebrata,' for 'female parts' of *Orthoptera*, p. 404, 8vo. 1855.]

[3] [Hunt. Prep. No. 2328 (*Bombyx Mori*).]

[4] [On the ventral surface.]

passes the urethra. From the root of the penis passes a duct which is strong and thick at the root, but becomes smaller and smaller, and makes a twist or turn upon itself, where it becomes very small. Into this one canal, enter four pairs of ducts; the first pair are two long small ducts, each of which is coiled upon itself so as to occupy but a small space; the second pair are larger, and are the common 'vasa deferentia' of each side; the third pair are two pretty long ducts, nearly as large as the vasa deferentia, that take a slight serpentine course, there being room for them in the abdomen; and the fourth pair are two small short ducts between the two last. The testes are twelve on each side, [the insect] having twenty-four in the whole! They are round flattish bodies, each having a duct passing out of its centre like the stalk of a mushroom, which is of some length; and the whole twelve ducts unite into one, which forms the common vas deferens of that side. I once saw them in copulation, which was exactly similar to [that in] the cock-chafer.

Moths are a long time in the act of copulation. The large moth is some days.

Of the Laying of the Eggs of Moths.

In a middle-sized perfect white moth[1], about the size of a silk-moth, the female has a great deal of light brown hair all round the anus. When she lays her eggs the oviduct is protruded, and when the egg is three-quarters out, she moves the anus from side to side, which brings the protruded egg in contact with the hair, which attaches the hair to the egg so strongly as to pull the hair out by the roots, so that the egg becomes surrounded by them. These hairs, by means of the mucus, stick again to the surface on which the eggs are laid. Putting some of these eggs under a glass shade, in about three weeks they hatched; and the young worms worked a network all over the inside of the glass.

In July 1791, I found one of these moths laying its eggs on the leaf of the Paper-tree[2]. I took the moth into the house with a part of the leaf, with some of the eggs on it, with a view to preserve it as a preparation[3].

Longevity of Insects according to Period of Oviposition.

I do suspect that the females of insects, respecting longevity, are of two kinds; one where the female dies the same season in which she is

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[1] [The accomplished entomologist, Francis Walker, Esq., believes the species here referred to, to be the 'Brown-tail' moth (*Porthisia chrysorrhœa*).]

[2] [Paper Mulberry (*Brucea papyrifera*).]

[3] [Hunt. Prep. No. 3043, shows the eggs of a Hawk-moth (*Smerinthus*) attached to a leaf.]

hatched, as in the silk-worm; the other where she lives through the winter following her being hatched, and in the summer lays her eggs and dies; as I fancy is the case with most flies.

[*The same idea differently expressed.*]—Insects which lay their eggs in one season, which eggs do not hatch till the year following, I suspect are only annual, or live only that season; such as the silk-worm [*Bombyx*], black-beetle [*Geotrupes*]. But insects, whose eggs are laid and hatched the same season, must live in two seasons; at least they must live one winter.

[*The same idea differently expressed.*]—I have an idea that all insects which lay their eggs in the autumn, to keep through the winter, to be hatched the next summer, and which therefore were themselves hatched that summer, such as the silk-worm, die themselves in that autumn; but that those which lay their eggs in the summer to be hatched in the same summer, have the young of those eggs living through the winter to lay eggs next summer, as their parent did; and probably they themselves die in that autumn[1].

The males of some species of insects live through the winter, while the males of other species die in the autumn of the same summer in which they were bred.

In the history of most insects there is a chasm which is with difficulty made out; but probably this is only in the insects of those countries that have great variety in their seasons; therefore such insects as become inactive in cold weather, and have not provided for themselves, as bees do, become obscure in that season. [The history of] those which do not live above one season is also obscure, for it is not always known when they die. The history of the silk-moth, which is of this kind, is probably the best ascertained, because it can be domesticated; and I think we have reason to believe that all moths are of this kind [a like nature]. But what becomes of many flies, and of all of the bee-tribe, excepting the common bee, is what I do not know[2].

All of the flying class of insects make a complete history of themselves every year; so that at any one period of the year their history may be begun, for it will be completed by the year following at the same period; for, although some live only the season they are produced in, such as the silk-moth, yet the period of the life of their eggs joined with their

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[1] [The three modes of stating the same proposition are here retained as exemplifying the pains which Hunter took to record his observations and conclusions with accuracy. He never could have destined such records to indiscriminate destruction.]

[2] [This may have been penned before the observations on the wasp, hornet, and humble-bee had been completed.]

own, completes the year. And although some of the females in the bee-tribe live sixteen or seventeen months, yet a complete history of them is to be formed in one year. How far the common bee lives longer than one year, I do not know; if they do, then it is only a continuance or repetition of their last actions of perfection, viz. propagation, and the few months they live longer than the year is only a continuation of these acts, which they completely performed within the twelve months.

Some insects are eggs, maggot, chrysalis and fly in the same season, as the common bee, wasp, hornet, humble-bee, common fly, &c. Others are only egg and maggot in the same season, as the privet-moth, some bees, some wasps which are a chrysalis through the whole winter, and fly the next summer. Others, again, are egg one season, [and are] maggot, insect and fly the next; as the silk-worm, cockchafer, &c.

Some insects appear to have three stages of life—the state in the egg, or of the fœtus; the worm-state; the chrysalis, and the fly-state. It is very probable that all those insects which form what is called the 'nymph,' 'chrysalis,' &c., are of this class.

I believe the maggot never changes its skin till it is going to form itself into a chrysalis, so that the skin grows with the animal; and it is probably not of the scarf-skin kind, but like the skin of the snail, earthworm, &c.

Caterpillars change their skin several times before they go into the chrysalis state. I believe their skin is to be considered as a kind of cuticle or horn[1], therefore it does not grow after a certain period.

Two-fold Birth of Flying Insects.

Animals of this class have two births, or may be said to have two conceptions; one from the egg, the other from the chrysalis. The exact parts formed in each state are not as yet known[2]. One would naturally suppose that all the vital parts were formed in the first stage, and the wings, limbs, &c. in the second: the first stage brought all the vital parts to their full size; and as the insect must have an addition of parts, or become another animal, it must lie dormant till such parts are formed. If this had not been the case, then they must have been obliged to change their coats or skin as they grew; like the lobsters, &c.

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[1] [Modern chemistry has shown it to be a peculiar substance called 'chitine.'—Lectures on Invertebrate Animals, 8vo. 1855, p. 349.]

[2] See Herold's 'Entwickelungsgeschichte des Schmetterlings,' fol. 1835.

Loose Notes and Queries on Insect-metamorphosis.

The maggot or caterpillar changing in every part, losing the old, and forming new out of the same materials, may illustrate the changes that take place in the matter of other animals. It may explain the change from cartilage to bone ; but, probably better, the changes that take place in newly-formed parts.

The grub, maggot or caterpillar [of an insect] may be reckoned more simple than when [it becomes] a fly; at least they are more simple in their parts of digestion, having hardly any intestine; which would incline one to suppose that an increase of parts, which of course produces an increase of action, requires an increase of intestine or digestive powers.

In insects, do the brain and nerves change equally with the other parts of the body? or does the same construction of brain, and identically the same nerves, answer two purposes[1] ?

When an insect forms itself into the perfect state in its pod, it cannot live long in that situation, for then it is a perfect animal, and immediately requires food. Therefore such insects as enclose themselves in the autumn, to live in that pod through the winter, lie dormant in the maggot or caterpillar-state till the spring or summer before they change into the fly.

Relation of generative Parts to Grade of Species.

The parts of generation in the more imperfect animals increase in size almost in proportion to their imperfect grade, so that the most imperfect are almost wholly genitals, as the polypus and tapeworm.

Loose Notes and Queries on Generation.

Is not the circumstance of mules not breeding a strong presumption that generation is performed by a mixture of perfect seed belonging to both sexes, and not dependent on one only? It shows that the seed of two different perfect animals cannot produce a perfect animal; owing, we may suppose, to that produce not being capable of producing perfect seed.

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[1] Had Hunter been acquainted with the great work of Lyonnet, 'Traité anatomique de la Chenille que ronge le Bois de Saule,' 4to. 1762, he would have found therein the answer to his question. See the abridged results of Lyonnet's and later investigations of this interesting subject in my 'Lectures on Invertebrata,' ed. cit., p. 359–366.

The offspring being like both father and mother, shows that both sexes are concerned; that is, both have a share in the thing produced; but why the offspring is sometimes more like the one than the other parent is not yet understood. Why are twins more like one another in bodily appearance than other children of the same parents?

Influence of the male on the gestation of the female, in sexes of different species or varieties.

On September the 24th, 1782, I had my heifer, which was then only sixteen months old, bulled by a small buffalo belonging to the Marquis of Rockingham. In the month of June, 1783, she was letting down her udder very fast, also her bearing [vulva] was becoming large and loose, so that I expected she would calve at about the usual time, viz. nine months from the copulation, which would have been about the 24th of June. About this time the udder was become extremely hard, and she was expected to calve every day; but she went on till the 10th of July, viz. sixteen days longer than common. By the time she had gone ten days over the usual reckoning, the udder was become so turgid and so hard that it appeared like the effects of inflammation, and appeared to be very painful. She could hardly walk or move her hind legs; the udder, either from size, pain, or both, interfered so much with their motion.

As I had thought it probable that the buffalo-kind might either go a longer or shorter time than the cow, and as mine had exceeded her time ten or twelve days, I did now conceive that the buffalo went longer [with calf], and that my heifer was dividing the time of her gestation between that of the cow and of the buffalo. But as the operations of the udder did not correspond with those of the calf and uterus as to time, I began to suppose that the operations [or constitution] of the calf directed those of the uterus, whilst the udder was directed by the natural and original operations [or constitution] of the cow. Having formed those ideas from the circumstances attending the present case, I ordered the cow to be milked, and about a quart was taken away the first time, and she was milked twice a day till she calved. However, this was not sufficient to stop inflammation, and she was like to lose one pap.

Relation of size of offspring to number produced and mode of development.

The [new-born] young of animals do not always bear the same size in proportion with that of the parent. This, in some degree, depends on number, and probably wholly so; but of this I am not certain. When we compare the foal with its mother, we do not find that disproportion which exists between one pig and its mother, or one puppy and the bitch. How far taking the whole litter together, as one, will bear the same proportion to the mother that the foal does to its mother, I do not know.

In the quadruped this relation, probably, varies the least of any; for if [the proportion be considered which] the whole litter bears to the mother, then the variation is in common about one to ten or twelve.

In other classes of animals which are oviparous, there is probably not that necessity for such nicety [in this relation]; yet, where they hatch their young, some proportion as to size must exist between the parent and generative product; for it must be always within the power of the parent to cover the eggs. However, even in this there is great variety, from the dove-kind, which only lay two, to the wren, partridge, &c., which lay sixteen. Here the bird would appear to be upon the same footing [as the beast].

But when we come to still inferior classes of animals, we find the relative size of the offspring to the parent to be much less. For instance, of a turtle [*Chelone*] above 200 pounds weight, the egg shall not be larger than that of a hen weighing only six or seven pounds. But then the turtle lays some hundreds of eggs, while the hen only lays from sixteen to twenty at most. The same, I should suppose, may be said of the crocodile: however, not of all of that class of animals; for in some lizards, as the 'savage of the woods' [*Thecadactylus lævis*][1], I never saw but two eggs in the abdomen; and in the viviparous snakes they are upon the same footing [as regards number of young] with those animals which are more immediately connected with the nourishing, hatching, &c. of their young.

The same observations are applicable to fishes; for those which are viviparous [*Spinax, Scoliodon, Torpedo*] have the fewest young: those which hatch, as the guard-fish [*Syngnathus*], the next; and the common fish, as the salmon, &c., the most of all; and, in the same order, the single young or egg bears a smaller proportionate size to the parent.

In the insect class, those which take care of their eggs or young, and have no assistance, have the fewest young; such I believe to be the case with some beetles, as the black-beetle [*Geotrupes*], some of the bee-tribe which have no assistance [*i. e.* no neuters or nurses], the wasp-tribe.

These facts show us why the young of many animals are so small,

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[1] [Hunt. Prep. No. 3332.]

although the parent is large, and renders the examination of such young so difficult. Thus it is very difficult to examine the peculiarities of the fœtus of a turtle, alligator, &c.[1]

Of the different proportions that different parts bear to the whole in Young Animals, compared with the Old.

The legs of young animals are much larger in proportion to the size of the body than in the adult; and many which seem to be arrived at their full growth, yet retain a degree of clumsiness in many parts: these remarks are very observable in the feathered tribes.

Of the Breast.

The breast of the female is covered by the true skin everywhere excepting round the nipple. The skin here is thinner, and seems to have more of the rete-mucosum under it. The cutis is redder, owing to a greater number of vessels at this part.

This is but little observable in children; but, as they advance in age, it becomes broader and broader, as if pushing from the nipple as from a centre, until they attain puberty, and then it seems to be at a stand. As it advances in breadth it heightens in colour, till it is of a fine crimson.

This 'areola' and other circumstances form the full bloom of virginity; but, when impregnated, and approaching, like the flower, to seed, the areola changes to a dark dirty brown, and becomes considerably broader. The change in colour is principally owing to the addition of rete-mucosum, which, becoming thicker here than in other parts, and the cuticle being thinner, it becomes more visible.

Upon this part of the breast and on the point of the nipple, there are placed a great many small glands. They appear very plainly upon the areola, making little risings. Those on the point of the nipple are not to be observed but by the mucus that can be squeezed out of them, being very different from the milk; and the same with the mucus of the others, and the orifices leading no further than the nipple itself. These glands are more evident after impregnation. The thickening of the rete-mucosum, and the discharge from these glands, will hinder any mischief that might arise from the child's gums and lips.

The cuticle part of the breast separates much sooner from this than any other, owing, perhaps, to the thickness of the rete-mucosum, as it is principally dissolved when the two skins separate, and the thicker it is the easier will the water insinuate itself.

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[1] [Which, nevertheless, Hunter had attempted, as shown in his preparations, Nos. 3357–3360, 3363–3374.]

In the nipple of many animals there is an erective power, which takes place only upon external stimulus; which erection straightens the ducts, and allows the milk to flow. There is also a sphincter muscle at the mouth of each duct, which, like other sphincters, is always acting, excepting when the milk is to flow. How far this sphincter is universal I do not know, but it is evident in those of large animals, as the cow, mare, &c. The relaxation of this sphincter does not arise from any natural action taking place in another part, like the sphincter ani relaxing from the stimulus of the fæces with the action of the rectum, but from a stimulus being applied to the external surface, which becomes the natural stimulus in this case. This stimulus is the mouth of the young, which, by its application to the external surface, causes the sphincter to relax; and by suction and external pressure, the milk is drawn and squeezed out, but principally by the last.

It is imagined by dairy maids that the cow has a power of keeping up, or letting down, her milk. That the milk does not flow so readily at first, when a calf is taken from a cow, as it does afterwards, I believe is true; but I believe that this arises from the maid's hand being a new and different stimulus from that of the mouth of the calf; and, therefore, till the nipple becomes accustomed to it, the sphincter does not so readily relax.

The oil in the milk is formed by the action of the breast. It is not a straining off of the oil of the body; for if it was, then the oil in the milk of every animal would be of the nature of the oil of the animal, which it is not. The milk would seem to be made up nearly of all the different parts of the blood; yet something is wanting, for the blood coagulates spontaneously, but the milk does not. However, when mixed with what is called 'rennet,' or with a solution of alum, or with an acid, it coagulates; then it is like blood.

The milk of animals differing according to the different sorts of animal, and also differing according to the state of constitution of the same animal, would show that milk is not simply the chyle; or else we must suppose that the chyles differ according to the above differences, which we cannot admit. It is the same let the food be animal or vegetable; and, if so, then it comes to the same thing whether you place this sugar-making power in the stomach, intestines, or breast; but as we do not find any such thing in the juice of the stomach or in the digestive product which has got into the intestines, we have no reason to suppose any. It is much more natural to suppose that this [saccharine] property is given to the milk in the breast; and this is not done by a fermentation in the milk, for no animal juices of themselves will enter into such fermentation; but it must arise from a power in the breast to separate such parts from the blood as constitute a new or saccharine combination.

The milk, being sweet and producing sugar, would seem to show that it went through the saccharine fermentation, and that its becoming sour is owing to this sugar.

Milk, while in the breast of animals, either separates into its cream and milk, or else it is very thick when secreted; for in cows, &c., when it has been long retained in the udder, the lowermost, or that which comes first, is the thinnest, and the very last of all is very thick and almost cream. Now this is most likely from [the milk's] standing; because, if a cow is almost continually milked, the milk is very thin.

Whatever is secreted from the breast during the time of gestation is generally called 'milk;' but it differs in almost all its peculiar properties from that fluid. First, it is not white, but of a greenish or yellow colour, often a mixture of both, has no sugar, is strongly impregnated with the neutral salts, does not coagulate with rennet or acids, but coagulates with heat like serum, and is much thicker in consistence. From this it would appear that when the vessels in the breast are preparing themselves for the secretion of milk, they are in some degree in a state of inflammation, or something similar to it; first, as it were filtering off the parts of the blood with but little alteration, as in the first formation of pus; but as this inflammation goes off, they are preparing for the true secretion, as in abscess, &c. However, it cannot entirely be a straining off of the serum, because there are much more of the salts in this fluid at this time than the serum of the blood contains at that time; therefore there is a peculiar power in the vessels of the part to separate these salts, as must be the case in the lacrymal gland of the eye.

Milk, when collected in the breast, &c., and not drawn off, but a certain quantity constantly confined, so as in some measure to distend the ducts, gives the stimulus of a non-secretion, or may be said to act as a sedative; but if the breast be emptied, and kept almost constantly so, which is generally the case when the mother gives suck, then the emptiness of the ducts gives the stimulus for secretion; and the more it is kept so, the more it secretes.

The secreting vessels of the milk are very much affected by the disposition of the animal for venery. I had a cow that often took the bull without breeding. Every time she was a bulling her milk was bad, and but little of it. This is observed by all cow-keepers; but the reason they give for the small quantity is "that she will not give down her milk."

Cream is an oil chemically combined with an animal substance, which is specifically lighter than milk. It is composed of round bodies swimming in the milk. This substance does not put on its globular figure because it is oily, and from oils having no attraction for water; because if it was simply so, as these globules came nearer to one another, they would be attracted and run into one another till the whole oil became one distinct part, which is not the case. Also, if this was the case, these globules would be of different sizes, which they are not; they are all of one size, whether they are brought near to each other, or are much diffused in the milk. This combination would appear to answer the purpose of bringing the oil into a middle state between oil and water, so as to render it miscible with water. Motion destroys this combination, and reduces the cream, or rather the oil of the cream, to a substance called butter, which is perhaps the only process that brings it to the state of oil. However, butter is not the simple oil; it is still combined with some of the animal substance, which induces it to crystallize in a greater degree of heat than does the simple oil. Heat will destroy this last combination entirely, and separate the oil from the animal substance with which it is combined; the oily part runs into common oil, and the animal part is coagulated into flakes.

Of the Situation of Nipples as related to the number of Young produced.

All carnivorous animals have more than two or three at a birth; but only some of the graminivorous [have so many]; therefore carnivorous animals have a number of nipples along the [abdomen and] breast. The graminivorous have commonly an udder only, which is placed on the pelvis. The human subject has but two nipples placed on the breast. It is said that the sea-horse (or rather mare) of Africa[1] has the nipples also upon the breast[2].

There are three situations for the nipples of animals, viz. the breast, the lower part of the belly or groin, and all along the breast and belly[3].

The first two situations are intended for those that have only one or two young at a time, because the situation will not admit of many

[1] [Hunter here alludes to the manatee, or sea-cow (*Manatus Senegalensis*), which, like the dugong, has two pectoral nipples: in the female hippopotamus now (1858) living at the Zoological Gardens, London, the teats are two in number, small, round, and inguinal in position.]

[2] [The ape and monkey-tribe (*Quadrumana*), the bat-tribe (*Cheiroptera*), and the elephants, both African and Asiatic, besides the *Sirenia* above cited, have pectoral mammæ.]

[3] [Hunter has added a note of another position:—"The ass has two nipples: they are placed upon the prepuce, almost close to the opening. The same in the mare and zebra."]

nipples. The last is for those that are intended to have many, so that from seeing the situation of the nipples of animals in general, we may judge whether they have one or more young at a birth; but this is not an absolute rule, for the guinea-pig has only two nipples, which are at the under part of the belly, arising from a flat breast, and she has generally four, five, or six at a birth[1].

Query, On the Suckling of the Whale-tribe.

How does the young porpoise or whale suck the mother? for in whatever position they are put respecting the surface of the water, that is, whether the mother has her back uppermost or undermost, the nose of one must be under water. The only way I conceive that they possibly can suck is by their having a turning motion, so that the back of mother and young shall come up alternately[2].

Of the Effects that Castration and Spaying have upon Animals.

In all animals we are acquainted with, we see distinguishing marks between the male and the female, exclusive of the parts peculiar to each. The males are generally strongest made, more compact, bony and muscular, although not always the largest, and the parts made for offence and defence are much stronger and fitter for such purposes. In many of the feathered class the male has parts for such purposes peculiar to himself, for instance, the spurs of the common cock. The male has a degree of irresistible dignity superior to the female. The natural covering, whether it be hairs, feathers, or perhaps scales, as in fishes, are more in quantity, or more beautiful, especially in the feathered class. The mind, like the body, has a superiority; as the body is capable of greater execution, so the mind seems to be conscious of the superiority that the

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[1] [The wild cavy or aperea (*Cavia aperea*, Linn, Rennger) breeds but once a year, and then has but one or two young; domestication and an abundance of food exceeding that to be obtained, and with much more risk and labour, in the wild state, have increased the powers of propagation beyond the natural limit, but have not led to the development of additional nipples.]

[2] [They have been observed to lie on the side, with the hind-part of the body a little twisted upward, so as to expose the mamma of one side.—Wm. Clift. The mammary gland in the whale-tribe has a large reservoir, and is covered by a strong muscle. A quantity of milk may be injected from the lacteal reservoir down the throat of the young animal, the larynx of which is defended by its peculiar form and connexion with the soft palate. There is a similar mechanism of the larynx in the mammary fœtus of the kangaroo, and the mammary gland in that animal is surrounded by a muscle for the purpose of injecting the milk down the throat of the prematurely born offspring. See Animal Economy, p. 392, and note.—R. O.]

body has, by which means its views become more extensive; and thence it may be said that 'Conscience makes heroes of them all.' Whether this superiority of mind be an original formation, or be dependent on this consciousness of the superior strength of body, I will not pretend to say; but it is most likely an original formation of the mind, but which is capable of being improved or increased by this consciousness.

The testes in the male and ovaria in the female are not only employed themselves and influence other parts in simple generation, but they influence the whole body and also the mind. This is only known by observing the difference between those animals that are allowed to keep their testes or ovaria, and those that are deprived of them. The males naturally incline as they grow (from the time they lose their testes) into the shape, &c. of the female of the same species, except that they do not lose the other genital parts peculiar to them, which however do not become so large as they otherwise would have done. They not only grow like the female; but, especially if deprived of the testes when very young, they exceed her in many particulars; for, to whatever degree the male has advanced in that shape that is peculiar to him, he keeps it after the testes are removed, and advances no further in that course. And if the male has arrived at full age before the testes are removed, he remains nearly in that state, and does not fall back into the female [state or form]. But, as the body becomes weaker, or rather does not grow so strong as it would have done in the perfect male state, and as the parts of offence and defence do not grow at all (as we shall see hereafter), the mind becomes suitable to such condition, and the castrated becomes of a milder disposition than he otherwise would have been, and indeed more so than the female. The desire for offence is much less, and the instinct for defence is soon overcome; so that a great degree of cowardice results.

This, however, is only in those animals which do not prey upon others for their food. Those that do so have the addition of the parts which serve for such purposes, and they retain the desire to use them. For example, a puppy that is castrated does not continue mild, nor does a kitten, because they are ferocious from the first. This is agreeable to our universal principle; for the females of such [beasts] as have destructive parts and corresponding dispositions, differ from the males in fewer circumstances, and of course the castrated male differs less from the uncastrated [than we find in herbivorous animals].

In the human species the shape of the whole body is altered, or rather takes another form, whenever the male is deprived of the testes. He becomes larger in his body; a greater quantity of fat is spread over the surface of the body under the skin. The muscles do not swell so much, which produces softness and delicacy of look. The hair on the face does not grow, nor is that which is over many parts of the body so thick or so strong. His shoulders do not project, or spread out so broadly. The hips become wider, and the thighs thicker with fat, in proportion to the other parts of the body, especially about the knees; from the knee to the thickest part of the calf, the leg becomes smaller, and of course from the calf to the ankle, so that the thigh and leg form a pretty regular cone with the base uppermost, much more so than in the perfect male. The voice continues soft and sweet, does not break at the time of puberty, but continues pretty strong. The perfect male does not grow so fast as the female, nor does the female grow so fast as the castrated male.

Other male animals, when deprived of their testes, have the same principle for alteration in the form of body, viz. a general declining off from the perfect male towards the shape, &c. of the female. For example, the bull is in general smaller than the cow. His horns are short; his face is broad, and covered with curly hair. The neck is thick, short, and broad, strong before, and deep in the chest. The cow is the reverse of all this. A bull-calf, if castrated when young, becomes still larger than the cow, the horns grow much longer, his face becomes narrower, and there is no long hair upon it; the neck does not grow thick, nor is it so deep in the chest.

The horse differs from the mare in his head being larger; his forehead is broader; his eyes larger, or he opens his eyelids more so as to expose more of the white, which gives him a more lively and fierce look; his nostrils are wider; his neck is thicker and more curved; his breast is broader, and is strongly made before, but is thin behind. The mare has none of these properties. A foal, if gelt when young, loses a disposition for such shapes, and therefore grows up like a mare; his head, neck, and fore parts are smaller, and his hind parts are broader and thicker than they otherwise would have been.

The stag is the animal that well exemplifies what we have been advancing, as he undergoes the same changes in common with other animals, and he has also, in some parts, annual changes while he is growing; and he continues these changes after he has arrived at his full growth; which changes entirely depend upon the testes.

The stag has horns; the hind has none. These horns in the stag are changed every year, the old ones falling off, and new ones supplying their places. For the first four years each new pair is larger and more complete than the former; and whilst the horns are growing, either before the first four years, or in any year after, they go through several stages before they are complete and fit to drop. If a young fawn be castrated these horns will never grow, in which he becomes similar to the doe[1].

In the dissection of a spayed sow the vagina was very small, was thin in its coats, and pale. The rugæ were very faint, became smaller and smaller upwards, and at last terminated in a blind point. This shows that in spaying they cut off the horns of the uterus, or rather the whole of the uterus.

It is hardly possible to fatten a boar. A bull has not nearly the same fat as a cow or an ox. The perfect female is not so easily fattened as a spayed one, excepting she be with young. In the castrated state the mind is perfectly at ease, and accumulation takes place; for whenever an animal, whether male or female, arrives at a certain degree of health and strength, their mind or constitution is immediately turned upon venery; in the male sooner than in the female; therefore she fattens more. A castrated and a spayed animal seem both to be in the same state with regard to the animal economy.

The following I had from Mr. Hutchins [collar-maker], who kills and disposes of from two to three hundred horses in a year. A stone-horse has but very little fat in comparison with a gelding or a mare. The fat of a stone-horse is not so solid as that of a gelding or mare, and is mostly diffused; but the fat of a gelding is mostly on the outside under the skin, whilst that of a mare is mostly in the abdomen.

Case of the Testes not producing their Influence on the Constitution.

A man, 27 years of age, came into St. George's Hospital with a sore leg. While in the hospital it was discovered that his testes were very small and soft. I examined them and found them as related to me. I then asked him the following questions:—First, whether they had ever been larger? His answer was they never had. Secondly, if ever he had any desire for a woman? Answer: he never had. Thirdly, if ever he had an erection? Answer: he never had. Fourthly, if he played with or touched the end of the penis, if it ever gave him any pleasing sensation? His answer was, it never did more than any other part.

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[1] [If this be meant for the fallow-deer (*Cervus Dama*), it is not a constant sequence. In a male fawn from which the testes, but not the spermatic chords, were removed, antlers were developed and shed annually; but they were smaller and were retained longer than in the perfect buck. See my Osteological Catalogue, Mus. Coll. of Surgeons, 4to. 1853, p. 590. No. 3559. "Antlers shed by the above 'hevier' when he was five years old, in Oulton Park, Cheshire: presented by Sir Philip de M. Grey Egerton, Bart., M.P."]

On examining his beard, it was only a kind of down, with some stronger short hairs in those places where we find them in lads, or women who have a beard; viz. principally on the upper lip, and a few on the chin longer and straggling; nor had he hair on any part of his body where men commonly have. The hair on the pubis was as it commonly is.

From the above facts it would appear that the testes had never produced their effects on the constitution; and that so far he was to be considered an eunuch. He looked older than 27. However, he did not look like a woman, nor had he the make of one. As the hair on the pubis is common to both sexes, it was expected to be there as it commonly is.

Enlargement of the Breasts in the Male.

Those cases of hermaphroditical monster in the human body, characterized by an increase of the size of one or both breasts, are usually seen about the age of puberty, although not always. It is generally attended with considerable pain at first, but this afterwards goes off. Mr. Cadell's son was a strong instance of this pain. His breasts vary as to size, being sometimes larger than at others.

[Hunter then gives brief notes of five other cases of enlargement of one breast, in men, from sixteen to twenty-seven years of age, observed by him between the years 1784 and 1790; and finally cites the following:—]

Extract of a curious case from Cumana, published and properly authenticated by M. Naverrete, Treasurer to the Army and Receiver-General to the Royal Finances, &c.

"Mr. Anthony Lozana, a native of Pamplieya in the diocese of the Archbishop of Burges, formerly servant Commissioner to the Convent of St. Francis, and now a schoolmaster among the Indians in the Canton of Arenas, Tributaries of St. Ferdinand, aged 50, of a middle size, temperament cachectic, between phlegmatic and bilious, soft fibre and flesh delicate, like women; feeble voice; few hairs in his beard, and none at all on his breast, with weak eyes; was married to Leonora Maria Parejo, who, fourteen years ago [*i. e.* from the date of this Memoir], brought forth twins, the one male, the other female. To soothe the cries of the male child, the father used to apply his left nipple to the infant's mouth, who sucked and drew milk from it in such quantity as to be nursed by it in perfect good health. He treated all his other children, eight in number and all alive, in the same way, always dividing with his wife the business of nursing the children and taking care of their domestic concerns. But, what is very remarkable is, that, ever since, he has had a constant flow of milk from the left nipple, whereas in women it always ceases soon after they give up nursing.

"The man has been subjected to various trials, and examined very accurately by Messrs. Castallar and Caballero, physicians and surgeons to the army. His genitals were particularly inspected, but there was not the least appearance of his being an hermaphrodite, or of any difference from other men. The lymphatics, blood-vessels and conglomerate glands of his nipple presented the same appearance which they do in women. The father himself remarks that his nipples were more turgid, and that the flow of milk was more copious, of a whiter colour and thinner, when he suckled his first child than at the time of his examination; that at the same time all natural excretions were much diminished, especially the sweat, to which he was much subject before; and that he had not the least appetite for venery for several months after. On the 4th of March, 1786, in the city of Cumana, before the commandant of the town, Colonel Lascanotegui and the Lieut.-General Bailets, and several others, Mr. Lozana filled a spoon with the milk of the left breast, which was of a yellowish colour; and he drew a small quantity from the right nipple."

ON MONSTERS.

Introduction.—Nature being pretty constant in the kind and number of the different parts peculiar to each species of animal, as also in the situation, formation, and construction of such parts, we call everything that deviates from that uniformity a 'monster,' whether [it occur in] crystallization, vegetation, or animalization. There must be some principle for those deviations from the regular course of Nature, in the economy of such species as they occur in. In the present inquiry it is the animal creation I mean to consider. Yet, as there may be in some degree an analogy between all the three [kingdoms of Nature], I shall consider the other two so far as this analogy seems to take place.

As every animal is formed from a portion of animal matter endowed with life and actions, being either so arranged in itself as only to require new matter for it to expand itself according to the principle inherent in itself,—as in all animals produced from semen, deposited either in a womb or an egg, or where any portion of an animal shall, out of itself, produce an animal similar to itself, as in the polypus,—

these first arrangements go on expanding the animal according to the first principles arising out of them[1].

Whether the principle of monstrosity be coeval with the first arrangement, or arise in the progress of expansion, is not easily determined in many [instances of monstrosity]; but it is certainly not the case in all; for many take place at a late period, and would seem to be owing to accident, or to some immediate impression; but still there must be a susceptibility for such, which susceptibility must be original.

Most preternatural formations of the body which a monster is born with, arise, I should imagine, out of a defect in the first arrangement of the original matter. However, it may be possible that accident in the womb or egg[2], or a defect taking place there, might be a means of producing a double part, or might hinder a part from forming altogether, or [might cause] even a preternatural formation. Probably Monstrosity might be reduced to the same principle as that of accidental injury, from which the parts cannot recover perfectly, but recover defectively or with deformity.

In animals, it may be a question whether monsters of all kinds are as common to them in a state of nature as they are in the cultivated state. I should suspect not. This we are certain of, that so far as size, shape, colour, peculiarity in the coverings, modes of defence, [&c. are concerned, these] are all varied from the natural state by cultivation. This is shown every day in domestic animals.

Monsters are not peculiar to animals: they are less so in them, perhaps, than in any species of matter. The vegetable [kingdom] abounds with monsters; and perhaps the uncommon formation of many crystals may be brought within the same species of production, and accounted for upon the same principle, viz. some influence interfering with the established law of regular formation.

Monsters in Crystals.

Monsters in crystals may arise from the same cause, as mentioned in the 'Introduction;' viz. either a wrong arrangement of the parts of which the crystal is to be composed, or a defect in the formation, from

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[1] [Paraphrase. Every animal is formed from a portion of animal matter endowed with life and actions, which is either produced from semen deposited in an egg, or from a part, or bud, of the parents' body, having in both cases a power of expansion if due material be supplied; and expanding according to the original principle of growth peculiar to the species.]

[2] [Geoffroy St. Hilaire is said to have made monsters by covering part of an egg with a layer impenetrable to the atmosphere during its incubation.]

the first setting out being wrong, and [the formation] going on in the same [wrong] line. The principle of crystallization is in the solution; yet it requires more to set it a going, or into action, such, *e. g.*, as a solid surface. The deficiency in the production of a true crystal may be in the solution itself; or, I can conceive, that a very slight circumstance might alter the form of a crystal, and even give the disposition for one [crystal] to form upon another. Quickness in the progress of crystallization produces irregularity and diminution in size. Crystallization, moreover, arises out of the property of the parts to compose the crystal, and the effect is more similar to art than the increase of either a vegetable or animal.

Monsters in Vegetables.

The formation of a vegetable is, in its manner, very different from that of a crystal, although somewhat similar in effect. It takes its rise from a peculiar modification of matter, having a power of action within itself, capable of changing matter into its own kind, and disposing it for the increase. But the increase is somewhat similar to that of the crystal, for it is laid on the outside of the part already formed, increasing the size of the whole both in thickness and length, but principally the last.

In the vegetable Nature has not been so attentive to the constant uniformity in the formation, situation, and construction of parts, as in the animal; and therefore such variety is more frequent than in the animal. Perhaps there are few vegetables but have something of a variety in them, because they are bound to no regularity in the number of their parts: but they are pretty perfect with respect to the bad form of their parts[1]; the parts, whether supernumerary or not, being pretty perfect in their form: for, in vegetables, an exact uniformity was not wanted; because all the parts have nearly the same use, which is not the case with animals. Each part in an animal has a use appropriated to itself; from which [circumstance] supernumerary parts become of no use, and deficiency is an evil.

The frequency of this variation in vegetables seems to arise from a vegetable being at all times under the influence of that principle which is capable of producing a variety when the immediate cause is present; for this principle exists as long as a vegetable has the power of forming a new part, which is as long as it grows; because a vegetable can, and is always producing new parts. For besides the growth of the new

[1] [Meaning that they are less subject to malformation, than to abnormal number, of parts.]

matter on the end of an old branch, or that of new branches, there is every year a layer of new wood laid upon the outside of the former wood. This new layer, when forming, has the power of producing a new part, and never afterwards. Cut off a branch, and you will find that the new layer forming round the cut surface receives a stimulus arising from the want of power to continue this part of the tree, which stimulus produces a new branch or branches. But an originally formed part never produces a monster or a new branch; we never see a monster or branch arise from the cut surface of an already formed part of a vegetable. In a vegetable it is always in the production of a new part, not in the growth of the old, that monsters rise up. If a vegetable meets with an accident which interferes with the natural growth, it then forms itself into another growth. If a natural branch decays, or is destroyed, two or three shall arise in its place, all of which are so many monsters; and we may observe that they are similar to the other parts of the tree from which they arise. If it is in the root, a new root is formed; the same of a branch. They are only supernumerary parts; and this arises from a vegetable consisting only of two parts, the old and the new; the one only a repetition of the other; which is not the case with many animals that admit of monstrosity.

Many plants have a deficiency in their shoots. Hence a vegetable can be made to grow of a very different shape from that which it would have done naturally. A tall thin tree can be made to grow short, thick, and bushy, and *vice versâ*; but, still each new supernumerary part attains the character of the tree and produces the same seed.

The great principle of monstrosity in a vegetable relates to the constant property of forming new and similar parts, and to a stop being put to, or a violence committed to, the natural growth of one of these parts.

Monsters in Animals.

As there are monsters in animals, let us see how far they are or are not reducible to the same principle as in minerals and vegetables. The first formation and growth of these are not similar to each other; however, the vegetable and animal have the closest analogy[1].

I have observed that a crystal forms and increases according to the nature of the parts of which it is to be composed; and this is common to all kinds of earth: but I observed that a vegetable is formed of a peculiar modification of matter, and that common matter must be first modified by the actions of the vegetable itself; and this matter is dis-

[1] [Hence the present received division of Nature into the Organic and Inorganic Kingdoms.]

posed on the external surface of the vegetable; in effect, similar to the crystal; so that the vegetable works up itself. Animal growth is so far similar in being [seated in] matter of its own, formed so by the animal itself, and disposed of by it: not by accretion as in the crystal; nor by disposing its own materials on the outside as in the vegetable; but by an interstitial deposit of its own assimilated matter, by which the whole is expanded.

An animal, like a vegetable, has a portion of its own matter so arranged as to have the power of growth, and the first principle of monstrosity may have taken place in this first arrangement; and what makes this very probable is, that most of the monsters are formed as early as we can observe any formation. However, this is not always the case; therefore we have monsters before birth and after; which I shall consider further.

Monsters before Birth.

The first class of monsters in animals are those that are born so. Now let us inquire in what respect is an animal, some time before birth, similar to a vegetable, or to the parts of animals which have the power of regeneration after birth. We are to consider, first, that the life of an animal, before birth, is very different from what it is after. This difference in the principle of life [before birth] comes much nearer to vegetation, and most probably the further back we go, this similitude is the stronger. I fancy in this inquiry we must go as far back as the first formation of the animal, when the matter is moving into different forms, similar to the formation of a new layer or a new shoot in a vegetable; for in neither animal nor vegetable are the parts formed at once. A vegetable is, at all times, similar to the first formation of an animal, or to the new formation in a lizard's tail. These [*i. e.* the growing branch or regenerated tail] meeting with obstructions to their [proper] forms readily admit of duplication; but I believe seldom of more.

That it [the principle of monstrosity in animals] is as early as the first formation, appears from the supernumerary part being almost always placed with the natural or corresponding one; viz. two heads are always on the shoulders; four legs are always placed at the lower part of the belly; a supernumerary finger or toe is on the hand and foot; &c.*. Even in the hair, &c. the monstrosity is similar to the original[1].

* This, however, is not universally the case, as I have a young duck with a foot growing out of its head. [Hunt. Prep. Series of Monsters, No. 31.]

[1] [See also the subsequent 'loose note,' p. 251, for further illustration of this important principle.]

As far as I have seen, supernumerary parts never exceed double the natural number.

An opinion has been advanced that, where there are supernumerary parts, they have belonged to another or twin; that the supernumerary part was the only one remaining of one of these twins; and that it had grown to the other like budding in vegetables, or transplanting in animals.

But monsters in the bird-class entirely contradict this idea. For, in the cicatricula of the egg there never are formed two chickens; but, when a twin is produced, it is from two yolks: we have, however, monsters in chickens[1]. Would not the circumstance of a supernumerary part of an animal being at the command of one, rather contradict the idea of its being a part of another animal engrafted on the one possessing it?

As the first principle in a fœtus is the production of new parts, and as it loses that principle as these parts are formed—afterwards only perfecting them—we are to study the fœtus [in reference to the principle of monstrosity] at as early a stage as possible, and consider how parts may be badly formed, how they may be increased in number, or how they may be diminished.

A part having the power within itself of elongation, will have the power of varying in that elongation according to circumstances; therefore a head not yet formed, but only having a disposition to form, may by some accident be disposed to be formed into two heads, and the same with every part of the body.

On the other hand, that, or any other part, may lose the disposition to form at all, and [the fœtus], therefore, be deficient in such part; or the disposition in the part for growth may be imperfect, and then there is no knowing what form it may be of, just according to the nature of the imperfection.

A deficiency and a mal-conformation are much more easily conceived than the formation of an additional part; for, in the first, it may be owing to a part's dying outright; and, in the second, it may arise from a part's dying in part, or irregularly, by which means the living parts will shoot out irregularly.

We have one part dying [as to function] when we come to full maturity [qu. old age], viz. the testicles. Now if these were to die before birth, the fœtus would be reckoned a monster; therefore, as we can produce monsters with supernumerary parts both before and after birth, we may reckon them as monstrous deficiencies after birth.

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[1] [Hunt. Preps. Series of Monsters, Nos. 40–44.]

Of Monstrosities after Birth.

These occur only in certain classes of animals, and in particular parts of these classes. Under what circumstances are these parts different from other parts of the same animal? Or, in what do they differ from animals in general? Or, in what respects are they similar to the vegetable? These parts are such as, when removed, grow again. This circumstance makes them different from every other part of the same animal, and also from every other already formed animal; and in this respect they also differ from the vegetable*.

It is this property of new growth in these parts that gives them a capability to form monsters in these parts, which they readily do: thus we see in a lizard, which, having lost its tail, has the power of generating a new one, that in such we often find a double tail, arising from the broken part[1]; similar to two or more branches arising from the edge of the cut surface of a branch removed [from a tree]. Lizards therefore have two or more chances or periods in which they can or may form a monstrous tail; for they have the first formation common to all animals, which should be called the first growth; and they have the accidental causes of a new or second growth, all which are due exactly to the same principle, viz. a new formation of a part. This, however, arises from an obstruction to the formation of one tail only; for, if the part which is to form the tail be slit but a very little into two points, these will form each a tail; so that an obstruction to the natural disposition becomes the cause of another taking place. I have seen this disposition so strong in the tail of the lizard, that a wound on the side of the tail has given the disposition for a young supernumerary tail to grow out of the wound†[2].

This sort of monstrosity does not take place in all the parts of animals

* It may be remarked that there is a difference in the setting out of the young shoot. In the vegetable it is from the circumference, or from the new forming parts; but in the animal it is from the cut end. This cut or broken end is exactly similar to a bud which is elongating,

† It may be remarked that in those lizards that have the power of regenerating the tail, the tail is so constructed as to admit of a regular breaking off. The tail is in regular rings, and readily breaks off at each ring, and the muscles break off at their origins and insertions, so that the broken end is very regular[3]. The separation is so easily effected, that if a lizard be caught by the tail, it will leave it in your hand by the strength of the animal only.

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[1] [Hunt. Preps. Phys. Series, Nos. 2219–3223.]

[2] [Hunt. Prep. ib. No. 2219.]

[3] [Ib. No. 2212.]

which have the power of regeneration; for the lobster which casts his claw, does not produce monsters or double claws. I am not, however, certain of this[1].

Monsters hereditary.

Monsters, or the deviations from the common course, or what may be called the original principles [types], in nature, have in them an hereditary principle. We may first observe that animals, not monsters in themselves, shall have the principle of producing monsters. I have seen three 'spinæ bifidæ' in the children of one family: in another family only having two children, both these had very large exostoses. I have seen two hair-lips in the children of the same parents. Dr. D. Pitcairn told me that the two tallest men he had probably ever seen were twins. They both came and enlisted themselves at Chatham in the train of artillery. One was six feet seven and odd inches, the other six feet five and odd inches: so far they were similar as to size. I have seen two watermen, twins, both stout men, and so like each other that there was no knowing which was which. Hence it is reasonable to suppose there was a disposition[2] in the parents to beget such. We find, also, that such monsters, once formed, have the principle of propagating their monstrosity. Thus I have seen a lady who had a hair-lip, and had two children born with hair-lips. Lady H. P. was born with a hair-lip: she had a brother born with the same, but who died when young; and her first child was born with one. A cow was brought to London for a show, which had a supernumerary leg upon the shoulder, which is a very common monstrosity[3]; but the curious circumstance was, she had a calf with the same monstrosity. Mr. Hudson, Apothecary in Panton Street, well known in the Botanical world, has a breed of cats without tails. The breed was first discovered in a farm-house in the country. The owners of the farm had forgot how long the tail-less cats had been there. Mr. Hudson has had several families of them, and the last included a variety, some without tails, others with short tails, and others with tails of a common length. It is more than probable that this breed arose from a kitten being brought into the world without any tail[4]. Sir C. C. had but one testicle that had come out of the abdomen,

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[1] [The Editor has seen a case of double pincer-claw on one side of a lobster; the two of that side equalling together in bulk the single normal claw of the opposite side. The antlers of deer offer instances of monstrosities occurring after birth.]

[2] [By 'disposition,' Hunter here signifies the inherent unconscious tendency.]

[3] [Hunt. Preps. Series of Monsters, No. 283.]

[4] [Very likely; but whence that tail-less kitten? In the 'Series of Monsters,' Nos. 308 and 309 show this 'malformation by defect.']

which was on the left side[1]: he was a married man, and had three fine children. This one [scrotal] testicle became cancerous, and was extracted; but the disease fell on the glands of the groin, of which cancer he died. His son, afterwards Sir C. C., a lad of about eleven or twelve years of age, died of a complaint in his lungs. I opened him, and curiosity led me to examine the scrotum, and I found but one testicle there; it was of the right side: the other testicle was in the ring. Was this similarity to the father accidental, or was it hereditary?

How far supernumerary parts are affected by the will.

Supernumerary parts may be so complete in their formation, as to become in some degree a part of the whole as to use. If such supernumerary part be endowed with powers of voluntary action, it is used at the command of the will. I have seen a monkey which had two feet on one leg (but which were rather two hands, each partaking much more of the hand than a foot)[2]; they, as it were, came out from one tarsus, with a kind of division in the metatarsus; but with only one thumb, which was on the inner side of the inner hand. The tarsus of course was broader than common. In the muscles on the leg which move the foot and toes, there was a strange jumble. The 'tibialis anticus' appeared to make the 'extensor radialis' of one of the hands, and the 'peronæi' made what could answer to the 'extensor ulnaris' which went into the outside of the other foot. The 'extensor pollicis' was pretty regular, for a foot, as also the 'extensor digitorum communis;' but, on the outside of these, between them and the two 'peronæi,' were extensors to the outer foot, or hand, which were peculiar to it. The 'gastrocnemius' muscle, which rose as usual, was inserted into a bone which might be reckoned either as 'os calcis' or 'os pisiforme'[3], and made either an extensor of the foot or a 'flexor ulnaris.' There was nothing that answered to the 'flexor radialis' of the fore-arm.

As these were two pretty well-formed hands, had full and free motion, and the animal made ready use of both, I found that the sciatic nerve of this [left] side was larger than in the other [right side] in proportion to their differences. This would make us suppose that it is not necessary that the constitution of the brain should perfectly agree with the constitution of the body; the brain being calculated for a more compound body than what it has; because a new part, having the powers of

[1] [That is, he had one 'scrotal' testicle, and the other 'inguinal,' or perhaps abdominal.]

[2] [On the left leg: see the preparation, Hunterian Series of Monsters, No. 279, 'Catalogue of Monsters and Malformations,' 4to. p. 76.]

[3] [Perhaps the earliest recorded idea of this 'serial homology.']

action, must produce an action in some common part of the brain, in order to put it into motion.

Do not monsters show that the mind and the formation of the body do not necessarily correspond?—that is to say, that the formation of the mind does not arise out of the formation of the parts; for although the body may be strangely formed, yet the mind, if properly formed, shall have all the natural dispositions for the natural actions of the body; just as if the body had been perfectly formed in correspondence with the brain; but as the parts are not formed for such action, they cannot be complicated. My monstrous horse, although the penis stood out behind, when erected, and did not come along the belly, yet leaped upon the mare to cover her, which he certainly would not have done if the instinctive principle of action had arisen out of the construction of the parts.

Are particular Species subject to peculiar Monstrosities?

It is more than probable that monsters are common to every animal; at least it appears so by all those we are acquainted with. From the rarity of any peculiarity in the production of malformations of any particular kind of animals, one would be inclined to believe that there is but one principle governing these formations. However, there are some animals that have a species of malformation peculiar to themselves, viz. the elephant-pig[1], which I never saw belonging to any other animal[2].

Classification of Monsters.

Of monsters there are two principal classes, viz. Duplicity of Parts and Deficiency of Parts; and there is a third class, viz. Bad Formation. The first is, by much, the most frequent[3].

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1 [The malformation alluded to is an appendage to the face like a proboscis, and is illustrated in the Hunterian Collection by young specimens of *Sus scrofa*: see Hunt. Preps. Series of Monsters, Nos. 160–162.]

2 [Sir Hans Sloane possessed one such in the human subject, which, with other anatomical specimens, was transferred from the British Museum to the Museum of the Royal College of Surgeons. It is now No. 159, 'Catalogue of Monsters and Malformations,' 4to. p. 45.]

3 [The specimens of monsters and malformations in the Hunterian Collection were arranged by its founder under the following heads:—

I. Preternatural situation of parts.
II. Addition of parts.
III. Deficiency of parts.
IV. Combined addition and deficiency of parts, as in hermaphroditical malformation.

For other classifications prior and subsequent to the time of Hunter, see my 'Note' to the Paper on the "Extraordinary Pheasant," in the 'Animal Economy,' ed. 1837, p. 44.]

In treating of Monsters, it cannot be necessary to give a minute description of all the preternatural formations constituting them; because many of their parts can explain nothing with regard to their formation, or the animal economy in general. For example, a supernumerary leg having vessels and nerves going to it, explains nothing in respect to either the use of vessels or nerves; two stomachs explain nothing in regard to digestion; two hearts nothing with respect to the circulation; and so on.

However, some of their structures may explain something in the physiology of the more perfect animals; just as the 'weight' in a clock might explain the use of the 'spring' in a watch, &c.; and, so far, it is right to examine them. The only thing which they would tend to throw any light upon, is the principle of animal life. One brain with two systems of nerves—two brains with one system of nerves—no brain at all—no medulla spinalis, or the communication between the brain and the nerves being cut off,—such monstrosities may explain a good deal with regard to the life and sensation of the animal. It perfectly explains the two states; viz. that before birth and that after; both of which are of considerable consequence[1].

On Hermaphroditism.

The parts of generation in animals being of a peculiar construction, and consisting of two opposite mechanisms, called the 'sexes,' we may suppose two very opposite principles [to govern their formation?]. We find that a degree of accuracy in this construction in both sexes is necessary for the intended use. But these parts are as subject to malformation as is any other part of an animal, and they are subject to a monstrosity [to which] no other part can be well subject; viz. a union of the two sexes, called 'hermaphroditism,' which is the most common; and the parts of the one [sex being] formed like those of the other, which is another kind of hermaphroditism. We have 'natural hermaphrodites' which may also admit of monstrosity: but this is not so easily ascertained; for we can make out the different parts of the sexes in a monstrous hermaphrodite much better than in the natural one; because we are perfectly well acquainted with the parts in the instances of their perfect division, as in the distinct sexes; but we are not so well acquainted with the distinct parts in the natural hermaphrodite;

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[1] [*i. e.* the explanation of the relations of the monstrosity to both states is of value in physiology; life and growth going on under the above-cited malformations, *in utero*; but subsequent air-breathing life requiring more perfect conditions of the nervous system.]

because they are not similar to those in the distinct sexes. If we could have a monster from a natural hermaphrodite, in which the parts of one or other of the two sexes only were formed, then we might make out the parts, as they are combined, in the natural hermaphrodite[1].

There are all degrees of monstrous hermaphroditical formations. It may be in a small or great degree in every part peculiar to the distinction of the sexes; or it may be only in one of the parts which distinguishes the one sex from the other. The occurrence in one sex of a peculiarity of the other, may be of three kinds. The first is a similarity of a whole that is common to both sexes, such as the body generally, but which has, naturally, a shape peculiar to each: for example, when a woman is shaped like a man, or a man shaped like a woman. The second is a similarity of a part which is common to both sexes, but which has naturally a size peculiar to each; as where the 'clitoris' of the female imitates, in size, the penis of the male; the breast of the male imitating that of the female; the spurs of a hen imitating those of the cock; a hen crowing, &c. The third is where the peculiarity of one sex is added to the other; as an ovarium added to a male, or a testis added to a female[2].

Loose Notes and Queries on Monsters.

A child, born at Brownlow Street Hospital, had what I should have called a divided scrotum, and the penis lying between the divisions; but it turned out to be a female. The external parts were the two labia, which were corrugated nearly transversely.

The natural structure of some parts of a fœtus are very different from those of the adult. These differences belong to the vital parts; they are adapted to the different way of life of the same animal [in those different states], and can be accounted for mechanically. But what is very surprising and unaccountable is, that fœtuses can live, in that state, with ill-constructed parts, such as are unnatural or uncommon, and not particularly adapted for that state, and yet they cannot live in another state. These are monsters; particularly those whose vital parts are deformed, defective, or with superaddition.

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[1] [The diversity of opinions, in later comparative anatomists, as to the nature of the several parts of the combined male and female organs in the earthworm and snail, shows how truly Hunter appreciated the difficulty of their determination. His preparations Nos. 2294–2315, showing elaborate dissections of species of *Lumbricus*, *Helix*, *Limnea*, *Limax*, &c., testify to the pains he bestowed on the investigation of the 'natural hermaphrodites.']

[2] [Series of Monsters, Prep. No. 236, 'Catalogue of Monsters,' 4to. p. 60.]

Now, why these fœtuses should live and come to full growth, excepting as to the part which may be deformed or defective, and not live after birth, is not easily explained.

I should imagine that monsters were formed monsters at the very first formation for this reason, that all supernumerary parts are joined to their similar parts; for example, a head to a head, &c.[1]

But monsters, in some cases, may be said to be accidental, as the horn growing out of the forehead of the ox or cow[2].

Is not the forked end of the fang of a tooth a species of monstrosity? and does not the manner of its formation show the nature of monsters, viz. two fangs being formed from a preternatural process taking place?

We often find in the human body an appendix or process passing out from the small gut; and I believe always from the ileum. In the year 1763, I found one of these in a body situated about one foot and a half from the cæcum. In the same winter I found another nearly three feet from the cæcum[3].

Double-headed Snakes.

America would seem to abound more in double-headed snakes than any other country. I have heard of several, by gentlemen who have been there, and I have two from that country in my possession[4]; but I do not remember to have heard of any in other countries. Both those I have heard of, and those I have seen, were small, not large or full-grown; therefore we may suppose they are not long-lived, but they are old enough to prove that they lived for some time after birth, having ate, &c., and that their death was owing to their having been caught; and that therefore they would have lived longer[5].

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[1] [Hunt. Preps. Series of Monsters, Nos. 190, 194, 264. The above 'Note' was probably penned after the reception by Hunter of the letter dated March 25, 1790, descriptive of the child having a second head, reversed, and attached by the vertex to that part of its own proper head. See Philosophical Transactions, vol. lxxx. 1790, p. 296.]

[2] [Hunt. Prep. Series of Monsters, No. 271. "The head of a cow with an additional horn growing from the centre of the forehead, &c.," 'Catalogue of Monsters,' 4to. p. 75.]

[3] [Ib. Nos. 295–298.]

[4] [Ib. Nos. 32, 33.]

[5] [Mr. Rembrandt Peale of Philadelphia, when in London with the skeleton of the Mastodon in 1802, told me that double-headed snakes were so frequently met with in America, that they considered them as species, and not as monsters: but he did not recollect if they were similarly marked. There were several specimens in his father's museum at Philadelphia or New York.—Wm. Clift.]

OBSERVATIONS ON PSYCHOLOGY.

On Consciousness.

What is meant by ' consciousness ' is, an impression of the mind of our own existence at the time, or rather of the existence of the mind and of its actions: for, I say "I am conscious that I exist;" which can be only in thought; for, that I exist in body, can only influence the mind by its being sensible of the presence [of the body], as it may be of any other body; for, although it feels its own body, and is conscious of it, it can also be made sensible of another body and is conscious of that also; therefore both [acts of consciousness] refer to the mind.

We can remember our being conscious of such and such things; for, we also say, that "I am conscious I did think;" that is, I have a clear conception that I did think. We also recollect what we thought about, and how. I say, "I thought honestly, and therefore acted accordingly;" but without a proof or sensation of it; for consciousness in the mind is totally different from sensation.

Therefore, when a man is conscious of a thing, he cannot be said to be sensible of it; for an act of the mind is not sensation. Consciousness is an act or impression of the mind which it cannot deny.

A man's feelings of himself, or consciousness of his body, is not sensation; for, when I was ill, my own feelings of myself, with regard to size, was [that I was] only two feet high, while the sensitive or the reasoning principle told me I was as tall as usual.

Consciousness is a conviction of the existence of one's self, or it is a feeling of itself, but is not sensation; it is the reflection on one's own existence, both as to personal existence and the existence of the mind.

Being conscious of a thing, is the strongest impression that can be formed on the mind; it is the act of the full powers of the mind, and is that which lasts, or constitutes memory. We often think of an act, and set about it, but in part forget it; and we go on with the act without being conscious of it; and if no circumstance or effect tells us that we have done it, we do not know that we have done it. A man shall remember to wind up his watch, and shall set about it; but another thought shall interfere; yet he shall go on winding up the watch, put it into his pocket, and immediately shall ask himself whether he wound it up or not; he only remembers his having thought of it.

If he was to think of taking off his shoes, and another idea should come into his mind, but he still should go on taking them off, he would not need to think whether they were off or not, for he would immediately find them off as soon as he thought about it.

We often act without being conscious of it; and that often arises from habit, and often, in a premeditated action, from the mind having lost its consciousness of the premeditation.

In another case the effect of the action shall not be exactly what was premeditated. For instance, I intend taking something into another room or to some person; and, instead of the thing intended, I take something else very different, a something probably I should not by any means have taken. This is what is called 'absence of mind.'

Consciousness may arise in consequence of sensation, but not from demonstrative sensation; for consciousness has always a relation to ourselves. All animals may be said to have consciousness, but cannot be sensible of it.

Sensation and demonstration are absolute and the same, and stand the first in order of evidence; they are that to which everybody gives assent. Perhaps conviction is the next or second [in order, or degree of certitude], and belief the third; but these three have a relation to other bodies. Conviction is an impression on the mind which is equal in that mind to sensation or demonstration; therefore it is not necessary first to produce sensation or demonstration. To produce actions will be according to the circumstances that become the cause of conviction, whereby our causes of actions, and our actions, are increased beyond what they otherwise would be.

A conviction of the truth of any proposition is the same as feeling the force of any argument or proposition; it is a perfect belief.

Belief is another impression of the mind, which is another substitute for sensation or demonstration, and which becomes also a cause of actions; but the impression is weaker than conviction, and is that which the mind or the reasoning faculty does not insist upon, as it does in conviction. It arises from a conveyance to the mind of a something that is supposed to exist but not demonstrated, only possible or probable; it arises from reasoning, and it is more than probable it is peculiar to the human species.

The first, or sensation or 'demonstration,' is absolute; but the second or 'conviction,' and the third or 'belief,' may or may not be so. Conviction requires the greatest evidence next to demonstration; and conviction is a greater degree of belief.

Consciousness generally relates to ourselves: it is not similar to a conviction of, or a belief in, other things.

It is of two kinds: one an acquired feeling, as "I am conscious to myself that I deserve it;" or, what is weaker, "I believe I shall get it." To be conscious one has done a wrong thing, would appear to belong to some brutes: a dog when he has done a wrong thing shows signs of it.

The other [kind of consciousness] is a natural or instinctive feeling or impression; for consciousness is not only a relation between me and some other thing as above stated, but has the same relation to the body. I am conscious of my own strength: I am conscious of my own weakness: we can even carry this so far as to say we feel our own strength or weakness. All animals have the same consciousness relative to themselves, which becomes one of the instinctive principles. A horse will not take a leap that he is not capable of performing: he is conscious he either can or cannot perform it.

How far these two [kinds of consciousness] are the same when they do take place I will not at present say: I cannot separate the impressions themselves if they are sensible, although I can the causes; but their effects are so much alike that they would appear to be one principle. They produce the same degree of confidence and the same degree of timidity. Confidence in the power assists the will: the sense of a want of power becomes a proper check upon the will.

This self-consciousness not only regulates many of our natural actions when in health, but the actions of the machine while under disease, both in the whole and in a part. We have an internal monitor of our powers, and we use them accordingly. This is often so strong that many know they are dying,—a thing they cannot know from experience.

This principle is even remarkable in parts that are diseased. I do not mean the active parts themselves, as muscles; for in such the disease might render them incapable of action, and of course no action could take place; but this consciousness of inability in other parts to support these actions, is a fact which can arise from no other principle than the effect or intelligence given to the mind of the inability of the part to support the action.

For instance, if the tendon of a muscle be broken, the breaking that tendon does not alter in the least the nature of that muscle, as a muscle; but, while that tendon is incapable of supporting the action of the muscle, that muscle will not act, and the mind is conscious of it; and, as long as the mind is in possession of this feeling, the will has no command over such muscle: but, as consciousness can only exist when we are awake, the mind, which is awake, while we are asleep, can and does put such a muscle into action[1]. The same thing happens when

[1] [We should now say that, because the mind is asleep, any stimulus exciting to involuntary or reflex action, operates by the wakeful 'sensitive principle,' unchecked, upon the disabled muscle.]

the mind acts instinctively, as when we are falling; the mind, then, immediately employs such muscles as are necessary for preservation; and, if this muscle [with the broken tendon] is one of them, instinct[1] lays hold of it; and the will which is checked by consciousness has no share in these actions, when the muscle is instinctively made to act.

A striking instance of this happened to myself when I broke my 'tendo Achillis.' While the parts were in a state of inflammation, &c., I, of course, did not endeavour to act with its muscles; but, when that inflammation had subsided, I found I had no power to act with the muscles of this tendon; and even when union had taken place and appeared to my senses, and of course to my reasoning faculty, to be pretty strong, yet I had not the least power to raise myself upon the toes of that foot; not even to make the muscles act upon that tendon. I endeavoured [to make them act], but to no effect; and the future power of the will over the action of these muscles was so gradually acquired, that I was convinced it arose from a consciousness of the mind of the inability of the tendon to support the action of the muscles, and all my voluntary powers were not able to counteract this impression. But I found that, in my sleep, I often hurt the young union of the tendon by the action of its muscles. And what was the worst, I fell, and tried to avoid as much as possible the instinctive action of recovery, but could not wholly do so; and the consequence was that the muscle acted and strained the young union very much.

This effect I have seen a number of times in strains in the joints; where mechanical strength was not in the least impaired, yet contraction of the muscles of that joint could not be caused by the will. There was that kind of inability as if the muscles had been in some degree paralytic, and which is expressed by the patient's weariness in the joint; although the real weariness is the inability in the mind to stimulate the muscle to action, from a consciousness of the impropriety of that action. The same thing takes place in fractures. The bone of the leg shall, for instance, be united, so as to have its mechanical strength as much as ever; it shall give no pain, yet the person shall not be able to put any stress upon it when put to the ground. Pressure would hurt the economy of the part, and therefore there is a consciousness of it.

Perhaps what I have called 'universal sympathy,' such as the sympathetic fever and the hectic fever—two constitutional affections arising from local injuries—may be a species of consciousness, not of the mind, but of the whole body; it being conscious of the state of the

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[1] [This term shows the double sense in which Hunter uses the word 'mind.']

parts. The first [sympathetic fever] is a consciousness of an injury done to a part which disturbs the whole: the second [hectic fever] is a consciousness of a local complaint, as if the parts felt themselves unequal to sustain it; whereby the constitution is teased into an action of which it cannot relieve itself.

Of the Mind.

The mind, or sensitive principle, is affected by objects which make impressions, which impressions make an alteration in the parts of sensation, and according to the nature of the impression so is the mind affected. If we see a man dance, the variety of actions produces the same variety of impressions, which impressions have simply an effect upon our minds. If it is a lively or quick dance, and not joined with distortions (which equally affect us), we feel lively; if it is a grave dance, we feel grave. The effect of the motion simply of other bodies upon our minds arises from an original property in the mind to sympathize with the cause of those actions, and to put itself into the same state in which the mind, or cause, is in which produces them; for, when the actions are various, the impressions are so, and the effect of these impressions is an inclination to put the body into such motions. This facility of a mind to be put into such a state by such impressions, will always be in proportion to the natural turn of that mind; so that the state of mind, which is naturally desirous of putting the body into certain actions, is also capable of being affected in the same degree by similar actions in another; so that a lively mind produces lively actions in the same person, and lively actions in another are capable of producing an increase of this lively mind and action in that same person.

The mind is not only affected according to the simple impression, as most probably is the case in brutes, but from experience, and association of other impressions or ideas with the present, it arrives at the cause of the actions which produced these impressions; and this always produces a stronger effect than the simple impression. So that an effect of the mind on the body is capable of producing an impression on the senses of a second body, which shall make the mind of that second body fall into the same state with the first or original mind, which shall produce the same actions in that second body with the first, and they shall all act in concert. For if the mind of the receiver attends to the causes of these actions, while the effects of these causes are producing their effects upon that mind, then the mind is still more affected; and the effect which arises from reflection is much stronger than that arising from simple sensation or impression.

Whatever actions affect the mind considerably, and more especially if the affection be joined with reflection, they make in some degree a lasting impression on it; or the mind more easily falls into the same state upon the simple recollection of the action and of its cause and effect. Indeed, there are in this affection a great variety of relative circumstances, which are so many heighteners of the effect; and the mind will fall into the same [state or affection] although the cause and effects are now become so weak as could not of themselves produce the original effect upon the mind: so that the mind now falls into that state merely because it fell strongly into it before. For instance, a man shall be strongly affected by a recent event and all its relative circumstances, &c. Simple recollection of those circumstances, or, what would be still stronger, if he be put into nearly the same situation as when the event happened, without its taking place, the state of his mind will be nearly that which it was in at first, although the original cause does not exist. For instance, a man shall be strongly affected by the death of a friend; and, more so, if there are at the time a great many relative affecting circumstances; such as the grief of other people, &c., to heighten the distress. But let some time elapse, and the true state of the mind will become really indifferent about the death and all its consequences; yet that man shall very readily fall into the same state of mind upon a relation of the circumstances, that made the first impressions, especially if in company with those friends, &c.

The mind is often in opposition to itself; one state of mind, if strong, shall get the better of another state which is weak, or the stronger state shall not allow the weaker to rise; although the mind is so circumstanced at the time as to have one state raised, if the other state which is stronger had not already taken possession of the mind, or driven the other out.

Nothing could show this better than two interesting facts which took place within myself, both happening at the same time. I went to see Mrs. Siddons's acting. I had a full conviction that I should be very much affected; but unfortunately I had not put a handkerchief in my pocket; and the distress I was in for the want of that requisite when one is a crying, and a kind of fear I should cry, stopped up every tear, and I was even ashamed I did not, nor could not, cry.

What we think of when awake, we only see in the mind's eye; but what we think of when asleep appears to be an object immediately of the senses. The objects in the mind's eye, when we are young, are almost real: we then can hardly think without the object presenting itself strongly in the mind; and if we connect a few of those ideas together so as to make a little train of thinking, it is almost like connecting real objects together.

We are very apt to go back into the same state, [as in dreaming or childhood] when there is a slight tendency to delirium; it may indeed be one of its first symptoms: [also when the] brain is slightly disturbed, as by a fit of gout, &c. But as we become used to see objects in the mind's eye, and to connect these objects together so as to draw conclusions, we lose the strong impression of the object on the mind; we hardly know it made an impression on the mind. We can connect imaginary objects, almost without seeing them, in the mind; just as we can work in the end at any handicraft, almost without seeing or hearing what we are doing. When we begin this, every object—every connexion of that object—is a fixed and determined one in the mind; and the hand is obliged to be directed in every movement by the mind; but, at last, the hand seems to leave the mind, and appears almost to go on of itself.

It is the same with the mind when it reasons: at first every object in the mind, not immediately an object of sensation, is almost realized, and seems to be of consequence; but as these objects become familiar, the impression is slight; and the acts of thinking and reasoning are done with so much ease, that the same mind is hardly conscious of them; for without being first conscious of a thing no remembrance of it can exist in the mind.

In many persons the mind hardly ever loses the susceptibility of a lively impression, and therefore they conceive such to be more than they really are: and I believe that such as have a lively imagination move quickly from object to object. This I believe to be a state of half delirium: I have felt this when much affected. Whatever I conceived in my mind became, at such a time, almost a reality.

Simple affections of the mind are those that are not immediately connected with any one particular action in the body, and which probably affect all actions alike; except there be one part [of the body], or the actions of some one part, more readily affected than other parts by such simple affections of the mind; which I can readily conceive to happen, and, indeed, which I know to be true. Mrs. Hutchins, for instance, was never much affected in her mind, but she had a purging. Other persons have this or that action increased by affections of the mind, but not more so by one than by another affection: such actions are only more readily excited by states of the mind than those of other parts of the body. But when a state of mind becomes immediately connected with an action, and the state of mind is in some degree formed upon the result of that action, there the mind will hardly allow that action to take place.

A man who is condemned to die next morning may so far make up his mind as to get some rest that night; and this rest will be more or less in proportion to the state of his mind. But if that man is to have his life preserved on condition that he does sleep, he certainly cannot sleep; the very anxiety arising from desire and fear will prevent him.

A fixed principle fixes the mind, but a doubtful one leaves it no rest. Anxiety is expressive of the union of two passions, 'desire' and 'fear.'

The state of mind has more effect on the actions of involuntary parts than on those that are at the command of the will. The reason of this is plain: the state of the mind finds no obstacle in its impressions on the involuntary parts, except what may be called natural to the parts themselves, viz. their backwardness to take on unnatural actions; but the state of mind has more difficulty in exciting the voluntary parts to action; for the will is often counteracting the actions that arise from mental emotion in voluntary parts, which produces an irregular action, as in trembling.

The actions of the mind of which we are sensible are as much the objects of sensation as [external causes of] sensation itself; we can reason about them.

The [state of] mind has two causes of its formation—the state of the body and sensation. Some states of mind are almost formed from the state of the body, as sexual desire; but it is heightened by sensation: other states of the mind are almost formed from sensation, as love, friendship, &c.

The feelings of the mind we often want to reduce to reason, or to that principle which arises entirely from sensation, viz. reasoning about real things. This becomes the basis of religion.

The actions of the body may be called insensible and sensible. In the first actions the mind is not directly sensible of them, although it may be so in a secondary way; as, for instance, the mind may feel uneasy or the reverse; although it does not know the immediate cause or action of the body which produces such feeling. In the second or sensible action the mind is made acquainted with them. The insensible actions or operations are often put into motion by the sensible ones; for example, the stomach is made to digest by the sensible act of throwing food into it. Or the sensible actions or operations may be set into motion by the insensible ones, as when the muscles of the penis are thrown into action by the insensible secretion of the semen of the testes; or when the bladder is thrown into action by the insensible actions of the kidneys.

The insensible actions are such as go on at all times, during health, whether we be sleeping or waking. Many of these insensible actions are immediately employed upon the machine itself; as, for instance, circulation, digestion, all acts of secretion immediately necessary for the use of the machine, as those producing bile, pancreatic juice, or to relieve the machine, as urine, perspiration, &c. But there are some of the insensible actions that depend upon other causes than simply the stimulus of the machine. Some depend upon the state of the mind, as the secretion of the semen; others have that dependence only for an increased action, as in the production of tears in grief or even joy, of the juice of the stomach and of the bile, in such affections of the mind as produce sickness. In some cases of affection of the mind from increase of secretion, the body must be under certain predicaments, such as hunger, when the idea of food or the presence of food shall increase the secretion of saliva.

As the increase of the secretion of the saliva arises from a state of body which is want, called 'hunger,' which, when joined with the idea of the presence of food, produces that state of mind which becomes the immediate cause of the secretion, so the secretion of the semen requires 'repletion' in the body, with the idea or presence of the proper object to produce the due state of mind; for the want, or the object alone, would not produce the secretion if a certain state of mind was not formed. Those insensible actions arising from the state of body, joined with the idea or presence of the proper stimulus, as food, or a female for instance, producing the state of mind, may take place whether we be asleep or awake; for as an idea can be formed when asleep, and as the mind can carry out that idea into ideal action, so the real action often takes place upon those occasions, and the saliva or the semen is secreted. When the semen is secreted, it is insensibly carried into the urethra; but when it has got there, it produces or stimulates the next action or actions immediately arising from it; but as this is a sensible action, it is capable of waking the person, and he often wakes in the act.

'State of mind' is most probably a compound of the state of body or of particular parts, and of sensation. It is what is commonly called 'the feelings of the mind.' The actions arising from the state of mind are 'instinct.' State of mind may arise from state of body only, as hunger; or from the senses only, as love; or from both, as love and lust combined; for these are two different feelings. A man may be in love, while he has no power of lust; a man may be lustful, and not in love. When a state of mind takes place without the natural leading causes, where reason is [not] called in as a director, it is madness.

If a state of mind be a compound of sensation and state of body, 'the fœtus in utero' can have no such state. If it be a compound of capability of sensation and state of body, the fœtus may have state of mind. This state is the first acting principle; reasoning comes on slowly after. It is the most universal cause of action in the body, making voluntary muscles act contrary to the will, increasing or diminishing the actions of the involuntary ones, and making many [involuntary ones] act which otherwise would not act at all, as those arising from some of the passions. The state of mind always arises from, or is connected with, external objects joined to some sentiment, either concerning itself, which may be called 'passion,' or concerning some other body, called 'sympathy.

The state of body from which the state of mind arises, may be called either real, as for example a child sucking, a duck swimming; or it may be imaginary, arising from habituated states or an acquired state, as when a man works himself into a passion, not arising from the state of body at the time, but from a repetition of a former action which arose originally from a state of body.

State of mind, whether fear or anger, produces many salutary effects on the body. A hare or fox runs away, and if that fails, it fights, a different action here arising from a very different state of mind.

State of mind produces actions of voluntary parts prior to volition, and indeed prior to sensation. A child moves its legs in the womb, moves the moment it is born, can and does cry as soon as it breathes. The calf, pig, foal, walks as soon as born; a duck, as soon as hatched, runs to the water the moment it sees it.

Nothing shows the effects of the mind upon the body more than the hatching hen. A hen shall hatch her chickens, at which time she is very lean; if those chickens are taken from her, she will soon get fat; but, if they are allowed to stay with her, she will continue lean the whole time she is rearing them, although she is as well fed, and eats as much as she would have done if she had had no chickens.

Of the Action of the Brain.

The brain is often so much employed in action, either in producing the mind or thought, that it cannot, as it were, be stimulated or impressed by the nerves, so as to receive sensation. A man shall be so much affected by some object as to render him incapable of either sensation or thought; or a man may be so far absorbed in reasoning as not to feel impressions on the body, which will prevent any anxiety that might arise from those impressions. Or the brain can be so employed respecting the mind as neither to feel the body, nor be capable of thinking, and *vice versâ*.

Many people have powers in the mind to reason upon subjects which are not present; they can start data, reason justly upon them, draw inferences, make conclusions. But if those data were to exist at the time, and they were to act justly, which would be putting their reasoning to practice, they could no more do it than they could fly. They would be bewildered between theory and practice, although their theory was just.

On the other hand, we shall find people who cannot start a datum, or form a position in their minds, reason upon it, draw inferences, &c. But, if put themselves into the position, and the circumstances were to happen (the same which the other foresaw, but could not act upon), they would take up the natural actions immediately as the circumstances occurred, and act rightly upon them.

Wish or desire is not instinctive; it is the union of two principles; it is the natural, attractive, impulsive act of the living principle, with the knowledge of the thing arising out of the sensitive [principle].

The simple desire in the mind to do a thing well is the first means of having it done well; but it has often two very different or contrary effects on the mind, and of course on the thing done. The simple desire procures the first means of having the thing done well, and the power of doing it is increased by that desire, and it is, in the end, as well done as possible for such powers combined. But when the future is in view, reasoning, or the will, is left free to act, and the voluntary parts are not wholly biassed by affections of the mind. This being the case, the desire may be attended with a species of doubt or anxiety, which always lessens the power of doing a thing well. Anxiety of mind interferes with the will, and lays hold of the voluntary muscles, and the well-performing of any action is in the inverse proportion to the anxiety.

On Reason.

Reasoning may be called either immediate or habitual: the immediate is when we are obliged to go through the whole process before we can draw the conclusions: the habitual is when we are so well acquainted with the subject as to draw the conclusions at once, as it were jumping over the investigation; but this often leads us into errors by taking premises for granted. Reasoning is used to determine or prove some fact that is only supposed [to be one]; or it may be used to prove that which has been already brought to light, but is disputed or reasoned against.

The improvement of the mind is by sensations. The mind has the power, called 'memory,' of repeating those sensations without the original impressions, and of combining those repetitions so as to form ideas, and then of combining those ideas so as to form a complete action, story, or proposition of any kind. By habit the mind does these operations with ease, and often goes on doing them almost without being conscious of it.

I believe that the will has no hand in any of the operations of an animal respecting the machine itself; but it is and can be employed in the operations that respect foreign matter.

Reasoning is fallacious if not based upon facts; but facts and reasoning should go hand in hand; for if the facts are not able to support the reasoning, then the reasoning is good for nothing: they should always bear a due proportion. If the facts overbalance the reasoning, and it requires a load of facts to give us a competent knowledge of anything, then they [facts or teachers] become dull and heavy.

The man who judges from general principles only, shows ignorance: few things are so simple as to come wholly within a general principle.

We should never reason on general principles only, much less practise upon them, when we are, or can be, master of all the facts; but, where we have nothing else but the general principle, then we must take it for our guide.

On Ideas from Sensation.

Perhaps sounds are the most simple sensations we have; for when a single body gives a sound, we do not know whether it is a simple sound or a combination of sounds. We suppose it simple, because we are not yet able to make any separation of the sensation; and by combination we are not able to bring out any sounds like those that are produced from the most simple percussion. Until Sir Isaac Newton separated the rays of light, white was supposed to be a simple colour. A body is of no colour when there is no light.

High or low sounds depend on the number of vibrations. Difference in sounds of the same height depends on the smooth or soft, and *vice versâ* of their motions.

We certainly know whence sounds come from habit, or by the intelligence of our other senses, as we know that there is something external that produces it.

The reason why we cannot tell or know what heat is, is because it is only capable of affecting one sensation, and that only in one way. Of bodies that are more gross, and capable of affecting the senses in more ways than one, and more than one sense, we can form an idea of their manner of action.

No man can have any idea of extension at first; his notion must come by degrees; the same thing must be repeated again and again; and the sensation that the notion of extension arises from, must become familiar: it is from motion in our bodies at first, joined with feeling, that we judge of extension or space; then time is compounded with it.

On the Command or Presence of Mind.

Every part that acts in consequence of sensation must be at the command of the will, for the will is formed out of sensation. The iris of the eye contracts immediately upon light being thrown upon an eye sensible to that stimulus, that is an action arising immediately from such sensibility. It is possible that we might not be able to imitate it by the will. But as the iris also contracts and dilates upon bodies being placed near or far off [the eye], we can, in the dark, contract our iris by putting the eye into that form which it assumes when it is viewing a near body[1]; and, on the contrary, we can make the iris dilate in the light [by putting the eye into that form], as when viewing an object at a distance.

As sensations form the will, so can the will attend to any sensation. The will can attend to one sensation out of many. In many sounds the ear can, by the will, follow one of them singly.

The mind is formed by habit, as the body is. The body may be made to endure many things, as fatigue, heat, cold, &c., without inconvenience to itself, or without making the mind sensible of it. The mind may be made to endure almost anything, and it may be so humoured as hardly to bear any inconvenience.

It is curious to see how much the mind, abstracted from the body, is similar to the body influenced by the mind. A man, when anxious to do a thing well, and more especially if another is in some degree concerned, seldom does it well; and, the more he endeavours, the worse he performs it; in like manner, if a man does not readily remember a thing, and becomes anxious to remember it, he will not in the least remember it, excepting some relative circumstance or connexion brings the thing into his mind. But if he can get naturally into the train of thinking that leads to the thing, without art or intention, he will immediately remember it.

Thus if a man were made to repeat anything he did not perfectly remember, he would probably forget how to begin. When he had begun, he might go on; but if he forgot any part, he would not find it out by the mind endeavouring to recollect it. He might go on if he began again; and would go on if he had no fears, doubts, or even thoughts in his mind, of the possibility of forgetting any part. If he could do it so carelessly as not to be conscious he was doing it at all, he most probably would go through the whole without interruption. So much is the train of habitual thinking interrupted by the immediate interference of the will, producing a state of mind which adds to the interruption.

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[1] [By the act of looking intently upon an ideally near body.]

Thinking is natural, but reasoning is not; we can think without reasoning. Thinking is the forming ideas. They may have a connexion with each other, so as to keep up a relationship, which might be called 'natural reasoning.' But reason is a kind of voluntary act; the mind brings itself to it. The first thing we lose when we are losing the consciousness of ourselves, is the power of thinking. When we can think we can reason.

That the mind has the power of producing actions in the brain is evident in many cases. The person who invented or applied the steam-engine to the sailing of ships, when it was before the Committee at the Rooms of the Society of Arts and Sciences, was taken at once with an apoplectic stroke, of which he died in about twenty-four hours[1].

Lord Eglinton informed me, whenever two soldiers were condemned to be shot, but one was to have a pardon, and they were to throw dice for their lives, that commonly the successful one fainted while the other remained calm. This would show that it is not the 'kind' of affection, but the 'quantity.'

A lady sitting up after every one was gone to bed, saw her door open, and a servant of the house come in with a pistol in his hand. She immediately blew out the candle, pushed the bed from the wall, and escaped between them. The servant in the dark pushed down the table she had been sitting by. This discomposed him; she came out of her hiding-place, got out of the door, and had the presence of mind to lock it. She awoke the house; and, as soon as she found assistance, or was secure, she fainted, and none knew what was the matter till she came to herself. The man was secured, and it was found he was out of his senses.

The various effects of the mind upon the body are almost without end; those, perhaps, are best known in many diseases of the body, but known only by those who have the diseases which can be affected

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[1] [I have been favoured by the following reply to an inquiry on this interesting statement:—

"Society of Arts, Manufactures, and Commerce,
Adelphi, London, W.C., 27th December, 1859.

"MY DEAR SIR,—I have had our records carefully searched, and I find no notice whatever of any such circumstance as you allude to in your note of the 24th inst. The only communication during the period named which had reference to steam power and boats is an anonymous one, 'On obtaining a circular motion for moving boats by steam,' which was not thought so good for the purpose as those already in use. What John Hunter could have referred to I am at a loss to say.

"Yours very truly,
"P. LE NEVE FOSTER, Sec."

"*Richd. Owen, Esq., British Museum.*"]

by the mind, and are only noticed by those who are in the habit of observing.

When I had the spasm in my heart upon the smallest exertion of the body, as in walking up a small ascent, or upon the least anxiety about an event, such as bees swarming, yet I could tell a story that called up the finer feelings, which I could not tell without crying, obliging me to stop several times in the narration, yet the spasm did not in the least take place [then]. Therefore those feelings of the mind we have for other people are totally different operations of the mind from that anxiety about events, whether of our own or of others; because its effects on our bodies are very different.

Laughing and crying are two natural involuntary actions in or of the body, both arising either from sensations of the body itself, or sensations only of the mind. Laughing arises from sensations of the body, as from tickling, and crying from that sensation called pain; but such effects are more common to the young than either the middle-aged or the old. This arises from the mind becoming more accustomed to sensations of the body; it is therefore less affected by them, excepting when the mind gets into the habit of those actions, which habit may rather increase than diminish them, as in spoiled children. The mind being pleased, and in a peculiar manner, produces laughter, and the mind being in distress, produces crying; but the same cause in the mind shall produce either or both, one following the other, as crying with joy. However, joy may produce crying much sooner than sorrow produce laughter, except when it runs into disease; so far [these emotional actions are] natural; but we have this carried into disease of the mind, but not of the body; we have either laughing or crying, called 'hysterics,' which are diseased involuntary acts; and the same cause shall produce either nearly equally, and much sooner than in the natural state; or the one shall run into the other; for instance, crying terminating in laughing, or laughing terminating in crying, which I believe is peculiar to this diseased state.

Joy and grief are, perhaps, the strongest affections of the mind, and what the mind has the greatest facility to fall into. They arise from an impression being made by some external object, or the mind sympathizing with the state of mind in some other object.

So far there is a visible and even reasonable cause, such as reason agrees to, [for those affections, and they then] might be called voluntary.

But the state of mind is often such as goes of its own accord into such affections, having no object for their cause, so that the mind passes from the one into the other almost instantaneously. These may, then, be called involuntary; the mind being as it is when some voluntary muscles act in spite of the will, as in cases of cramp, locked-jaw, &c. In the first, it is a state of mind produced by the senses which produces involuntary actions ; but in the second it appears to be the mind falling into them of its own accord.

On Fear.

'Fear' is a fixed or absolute principle in the minds of animals, but never in proportion to the real or apparent dangers ; therefore in most animals it becomes a relative term. In the human species it is allowed to act in a less degree upon its original principle ; it generally becomes so connected with some acquired principle as to be ruled by it ; therefore it is as the quantity of danger, and apparent inutility of that danger ; so that it would seem to be in an inverse proportion to the inutility of the hazard. Thus, take any cause for fear under different circumstances ; one where the natural fear is allowed to act, and another where it is either heightened or corrected by the imagination ; the degrees of fear will vary : the first or natural fear will be in a mean degree ; in the other it will be either increased or diminished.

A brave man of good sense will endure any pain, or the chance of it, in a good cause ; while the same pain, or chance of it, in a bad or even indifferent cause will make him a coward or make him shudder. The same thing holds good in animals in general ; only with fewer varieties, these being in proportion to the other varieties of actions. A dog is bold, although in considerable apparent danger when hungry, and food is by him, but a coward, perhaps, if without these circumstances. A cock fights better on his own dunghill than in a strange place.

Is fear a perfect and distinct state of mind ? Does it ever exist but in a doubtful state of mind ? Is it not a union of hope and despair ? for whenever hope is gone, fear diminishes. Is it not an anticipation of evil, and the less an animal has the power of anticipation, the less fear he has ? Dr. Dodd would seem to prove this[1].

The dull look in the eye in grief is mostly owing to the position of the eyelids. I can give a dead man almost any look.

On Superstition.

All innovations on established systems that depend more on a belief than real knowledge (such as religion), arise rather from a weakness of mind than a fault in the system. Everything new carries a greater weight with it, and makes a deeper impression on a weak mind.

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[1] [He was executed June 27th, 1777, which affords some clue to the date of this MS. He showed much fear of death, and intense anxiety to escape the capital punishment while intercession was making for him ; but he rose at once to a state of fortitude and resignation when all hope of mercy was closed.]

Having committed acts of violence always weakens the mind; therefore [it is the] more ready to fly to innovation, or to whatever seems most severe [by way of expiation].

On Deceit.

Perhaps there is nothing in Nature more pleasing than the study of the human mind, even in its imperfections or depravities: for, although it may be more pleasing to a good mind to contemplate and investigate the applications of its powers to good purposes, yet as depravity is an operation of the same mind, it becomes at least equally philosophical and equally necessary to investigate, that we may be able to prevent it.

The investigation of the mind's various operations at large, by which means it feels, thinks, reasons and influences the body either in voluntary or involuntary actions, is more than is requisite for my present purpose. The mind, like everything else, can be employed in promoting either good or evil actions, but it can as readily be employed in actions that seem immediately to tend to neither good nor harm arising from some strange or trifling impulse at the time.

When we consider the mind of man as possessing a thousand qualities which are distinct attributes in themselves, each being more or less contrasted by its opposites, as, for instance, intrepidity, fear; love, hatred; generosity, covetousness; pleasure, pain; anger, satisfaction; complacency, envy; humility, pride; vanity, diffidence; probity, deceit —all producing distinct characters, when acting alone, or when the one or the other is predominant,—we must be sensible how complicated the mind is; but as they [the qualities or attributes] are often mixed in the same person, they produce contrarieties in character which form the basis of all the oddities or inconsistencies we meet with.

One of the imperfections of the human mind is, the desire to be supposed what we are not, but what we should like to be. This arises from vanity, which, when well regulated, is perhaps a very necessary and useful principle. But we often wish to appear to be what we in reality hate, and are probably afraid of being, which would seem to be a strange contradiction in the principle of deceit. If the first deceit was always for noble purposes one would excuse the vanity; but it is generally for little selfish purposes, and might be called the 'childishness of manhood.' We are even jealous of those who may, with justice, be supposed to possess those qualities, in a degree beyond what we wished the world to think we ourselves possessed them.

No man is so fond of being thought brave as the coward, who would be really delighted if he was thought always to have an affair of honour on his hands; while the truly courageous man would rather affect the contrary. This is the same principle in both, but inverted: but the latter we admire. This admiration may arise from the amiableness of the person or of the principle, or because we do not feel him raising himself above us; so that it may be a selfish admiration.

No man is so fond of being thought a man of gallantry as he who has no passion for the female sex; yet would feel proud if it were conceived he had always some intrigue on his hands, even at the expense of the reputation of the innocent; while the man who is really passionately fond of the sex, and perhaps their dupe, would rather choose to hide that turn of mind, as if it were a defect.

We even choose to make our past sufferings a matter of admiration; and those who have the least fortitude under calamities, generally recite them with triple energy; which is a natural consequence, to excite either horror at their sufferings or admiration at their fortitude.

The same turn of mind is twisted into present distresses or sufferings, where it is to excite pity on false pretences, instead of admiration. There are many whose finger never aches but it is torture, who never measure anything that affects them by a common scale or standard, always over-acting their part, that you might pity; while, at the same time, you should think they were suppressing their sufferings that you might admire their fortitude or philosophy. This might pass with those who live by it, or have a secondary view; but when it is simply vanity, or simply to excite compassion, it shows a weak mind.

It only requires a stronger disposition of mind to continue the deceit, [as in a patient] when the disease is gone; when, if the complaint be such as cannot be wholly imitated, the patient will contrive some other symptom of another disease, or, if he has a lively imagination, even wholly a new one.

These general remarks must come home to the observation of most, if not a little to their feelings; and that which concerns disease must strike the medical man most.

Whoever has paid attention to this subject will agree with me in thinking that those minds are far from what they really wish us to think them to be; and that they are little minds. If medical gentlemen would apply this to their practical knowledge of mankind, they would see that their opinions of such minds and practice perfectly coincided; and, to strengthen this idea, let us see who they are that are most subject to practise this kind of deceit.

There are two classes of minds capable of carrying on this deceit. One is [influenced by] the love of imposition, and rather relates to those about them than to themselves,—a desire to make every one about them stare. Yet it cannot be called an amiable mind, for they must see every one about them in distress. Another class of mind is [influenced by] the love of ease ; and, therefore, to avoid something disagreeable, is sufficient to make them affect to be unwell. Those who are most addicted to this kind of deceit, are women and children. Women have it much stronger than men, because, from their birth, they meet with more indulgences. They are not allowed to have the idea of doing anything for themselves; by which means both the body and mind become indolent, relative to action; but [they are] extremely anxious to be pleased by others; and, if not so, then they feel unhappy. This is encouraged by men, till they are married; and the wives seem never to learn that the way to gain is not the way to keep; whereby they become disappointed, and then begin to practise arts either to excite jealousy or pity, but seldom admiration; just as they conceive the husband's mind to be most susceptible of.

Children are nearly in the same predicament; they are indulged by their parents; and, if allowed to keep company with the servants, they are certain to become deceitful and to learn a thousand ways of imposing on their parents. They are assisted by the servants, who sometimes benefit by it; or they, what is called 'curry favour with the young brood.' This is even more the case with girls than with boys; women being better teachers of this kind of imposition than men. If from such situations they go to the boarding-school, they stand but little chance of being reclaimed. There are numbers to keep them in countenance. At school they are less indulged, being more tied down to rules than they have commonly been, and a kind of private or mental opposition commences. Whenever they are taken ill they are immediately brought home, and having once regained a footing at home they endeavour to keep it.

Master Woodcock, twelve years of age, had a fever attended with rheumatic affection of the right knee. He was sent to the tepid sea bath, which (we may suppose) cured him, for he came home fat and jolly. However, the pain in the knee continued, and I was sent for to see him. When he came into the room he was limping on the left leg, while the right toe was turned in, from his limping. I conceived the pain to be in his left side, but found I was mistaken. He could hardly bear the knee to be pressed, it was so sore, nor straightened: he could not bear the toe to be turned out; and when I endeavoured to turn the thigh out, which motion could only affect the joint of the thigh, he could not bear it, although the knee was not, nor could be, affected. But his limping on the wrong foot was enough for me[1].

[1] [Mr. Hunter, on the morning of the day of his death, related to the house-pupils in the work-room several whimsical attempts at imposition in children to

Deceit appears to be a principle in most of the perfect animals, or those endowed with the senses. It is of two kinds, either to screen the animal itself, for its own safety, or to impose upon another for its own advantage, or for the disadvantage of the other. Probably in all animals it is instinctive, and has but little variety. But Man employs his reason, which, in most things, he does to improve or extend his instinctive actions; even to the creating new instincts. These begin very early, in the child, to become artificial. It hides its cake; it finds its natural and instinctive actions are checked, yet it practises them, of which practice it soon learns to evade the detection. It is encouraged by some of the older children; may even be assisted by those accustomed to evasion. They first put on an appearance as if innocent; if questioned, they deny. These lead to deceit of the mind, and may be called 'passive deceits.'

But the mind becomes more active; it is inventing actions, which actions are to deceive, without having committed them first; as it were, innocently, and then inventing an excuse as in the former stated cases. The first inventions are to excuse themselves from some task imposed, and they find out what will plead best in their favour. Health in young folks is a great object with parents, and the children find that out; therefore sickness is the great resource, as lameness or fits. Lameness is, generally, the first, because it requires the least art, and is more in the way of having been observed by them. Fits are not so commonly observed; and it requires a greater degree of mental powers either to put them on or go through with them; therefore we seldom have fits until about fifteen. The age of fits lasts longer in girls than boys; it even creeps into womanhood, but seldom into manhood; man beginning to employ his wits in another way.

Periods of Life, according to Appetites and Mental Operations.

The life of man may be divided into three great periods: viz. 'youth,' 'middle-age,' and 'old age.' In considering these three different stages of life, both as to constitution and disposition, we shall find that there is a gradual and imperceptible change always taking place; the first going gradually into the second, and the second as gradually into the third; so that there is no particular period between

avoid going to school. Referring to the present case, Mr. Hunter had desired the dessert for a dinner party to be laid out in the room where Master W. was laid up; and, being watched, he was seen to skip naturally and very briskly from his sofa, appropriate a bunch of grapes, and retreat with equal agility to his place of repose. The imposition was thus exposed, the culprit punished, but the surgeon was never again called in.—WM. CLIFT.]

any two of them whereby we can terminate the one and begin the other. Therefore we shall consider these periods when in their full maturity; and, as we proceed, shall consider the gradual changes into the next; as where the first is gaining, then losing, while the second is gaining, &c. But as these gradual changes are not so much, or so directly, to our present purpose, they will only be mentioned as circumstances taking place, that may, in some degree, throw a light upon our subject.

The first period of a man's life is [passed in] the enjoyment of its natural appetites and sensations, and [in] extending the actions naturally arising out of the union of the body and mind. The mind is constantly receiving impressions by its senses, and constantly forming new ideas, laying up a store of sensations and ideas; but, at first, without form or method.

New appetites are arising as the parts are becoming more fit for their peculiar sensations and enjoyments, which are always more vigorous in their early stages. So that a young animal is extremely active with regard to bodily action; being fitted for sensations and constantly in pursuit of them; yet it is extremely passive with regard to the combinations of the mind: it is just a being receiving impressions, thinking but little of the past; because the present enjoyment, and the future which is nigh, are the highest sensations of the body and the mind. These natural appetites are never improved; they are most perfect at the first, and will always be the most vigorous when the mind is least engaged, or when there is no mind at all. The natural or necessary appetites are limited: they are such as always destroy themselves by enjoyment, but are renewed again by the body recurring to its natural state.

This is the age that in some degree bespeaks the future with respect to intellect: it is the age that in most cases distinguishes the young man of feeling, sensibility, quickness of apprehension, from the idiot. The [state of the] idiot is one where impression produces sensation, not upon the mind, but upon the body; where the mind never makes an application of the present sensation to another; and where, when the present sensation is gone, it never recurs.

When the appetites for any one thing are vigorous, they carry us great lengths; but they are not lasting; for some new object of appetite appears, and destroys that for the former [object]. An appetite has but one fixed point in view: it is simple enjoyment. If it be the appetite of eating, it is intent only on eating; and if it fixes the mind on one kind of food, that desire cannot last long, for other food will exactly answer the same purpose. Or, if that [kind of food] is not sufficient at the time, hunger will come in and reconcile the whole; so that no man can think of any one kind of food for twelve hours. Therefore the simple disappointment of any one kind of food cannot long affect the mind; and, whatever may be the strength of a man's relative quality for any one kind of food more than another, it will be annihilated when he is set down to twenty dishes.

The same observations are equally just with regard to other appetites; only that for food, although the most essential to life, is the one that will produce the least effect upon the mind; and that arises entirely from its being the most essential. The other appetites, being less essential to life, allow the mind to dwell more upon them; and, to gratify them in a particular manner becomes more an act of the mind, than in the appetite for food. The enjoyment can be suspended in case all the relative qualities (either imaginary or real) are not present; and these relative qualities are more peculiarly mental than simple enjoyment is.

A man has an appetite to enjoy a woman; but if the mind has formed itself to any particular woman, the appetite or enjoyment can be suspended till that object is presented; and the more the mind interferes, the greater stress will be laid upon this relation: the mere sexual enjoyment will be almost forgot, and the whole pursuit will be after the particular quality of the appetite. But, perhaps, it requires long habit to establish the influence of such a relative quality in the mind.

Such is the state of youth till man arrives at full possession of all his appetites and sensations. Then he is in full powers of enjoying them; and, in this state of possession, he goes on for years; but his temporary appetites, as venery, become in time blunted, and often in some degree his essential ones, as that for food; and he begins to lose the substance in pursuit of the qualities, refining away the natural man, becoming rather ideal; whence arise 'taste,' 'graces,' &c.

The man begins to combine the sensations, and form ideas more extensive. From reasoning, he looks further forward; which, in a proportional degree, lessens the present [enjoyment], except it be connected with the future. He is considering substantials for the future, which always takes in a much greater scope of reasoning; as there are always a greater number of relative circumstances. He not only considers substances, but the qualities of substances, and endeavours to investigate, separate, arrange, and combine these qualities.

All these actions are of the mind; and as they took their origin from the nervous system, they continue to belong to it.

The mind now becomes the principal actor. It is viewing objects in all their different forms and relations; and, as futurity has both a good side and a bad one, the mind is apt to be more impressed with the one or the other, seldom steering in the middle. These different views of things will arise either from natural, or constitutional, or habitual causes.

It may be put down, as a rule, that everything in this world is absolute: but, as all the leading causes of things cannot be seen, because they appear to depend upon circumstances that are unknown, or appear to be accidental, therefore the mind cannot lead up to the absolute. It is influenced by some impression, arising out of the present appearances, which may be totally different from the effect that is to take place; and so the present probability, on one side or the other, determines the mind.

Thus, then, is futurity visibly left to be undetermined even to the mind of the most sanguine, which is perhaps the most weak. It leaves in the mind a strange disagreeable uncertainty, which the pursuit of present enjoyment does not produce; because the nearer an event is to happen, in the same proportion it seems the more certain to happen.

This age is the perfect age of man; and, at a medium, may be said to begin at thirty years and to end at fifty years.

This is the age in which the mind is truly employed; the age in which both the fear of disappointment, and disappointment, make a lasting impression, because the object to be gained is not momentary or immediate. Time hardly establishes a security: it rather exposes an uncertainty.

This is the age of madness; or when, usually, insanity takes place.

As people draw towards perfection they become more and more nervous: the nervous age is at about thirty or forty years; but as they go on towards the decline of life, they lose that sensibility. This is equally applicable to both mind and body.

One, at first, would suppose that the nervous state of body would be the young state; but it is not: this is a state rather of indifference to impression, although it may be felt acutely; there is too much love of variety to dwell long upon any one object: it is an age which feels quickly, but forgets soon.

Thirty is the time when objects begin to last, when they begin to make an impression, when they take possession of the mind. Fifty is the age when indifference about all objects begins to take place; an insensibility creeps on, the effect of which is similar to the first stage, although arising from very different causes.

Belief in general is stronger in children than in old people, although children are often deceived; yet the fondness for the thing carries them beyond reflection and remembrance of past deceits.

Young people like sugar; old people like pepper.

On Hereditary Right.

Hereditary right arises from the giver. Every man feels a desire to have property, and every man has a right to have property; and every man feels a desire to dispose of it when he can enjoy it no longer; and as it is his property, he has a right to dispose of it.

Every man feels an attachment to relationship. This naturally leads to bequeathing this property to his relations, and to the nearest: it is, in some measure, retaining it still. This property goes on in succession, from the same principle, and, when men unite for the benefit of the whole, they make this a law; because each has practised it, and is receiving its benefits, and wishes to continue them. This becomes a kind of reward for industry and for accumulation of property.

No man wishes to die, to be eternally forgot; what he leaves he considers, or he feels, in some degree perpetuates his memory, which is a means of incitement to great and good actions; and it is not in human nature to do good perfectly disinterestedly: he likes to have a share. If a man puts up a monument for a great man, he wishes it should be known who did it, and that the two should go down to posterity together. He is at the same time desirous that his son should come in for a share; he wishes the son should be known to be the son of that man.

On Sympathies.

Sympathies may be said to be of two sorts, natural and habitual. Without this sympathy few muscles would act; for few muscles are ever irritated themselves: but it is the part that is irritated which receives the benefit of the action. Laughing and many other motions of the muscles of the face arise from sympathy with all the senses that receive pleasure. Crying and many other motions of the face arise from sympathy with grief of all the five senses. Sympathy seems to depend on a kind of ignorance or novelty of sensation, which is got the better of by experience; therefore old people sympathize less than young. It is very remarkable that none of the sympathies can or ever are reversed, therefore they do not arise from the communication of the nerves, but from the effect of the brain upon the nerves.

On Appetite and Passion.

Would not the following be a proper distinction between appetite and passion?

Appetite is an action of the mind, arising from a stimulus given to it from some part of the body; and the appetite is this or that according to the part that so excites the mind; and, as appetite depends on a state peculiar to such a part, or natural to such a part to fall into, therefore it is always capable of being satiated. The part under such irritation puts both mind and body into such actions as will best satisfy or satiate the appetite.

Passion is an action of the mind not arising from any mere irritation of a part of the body, or from a stimulus given to it from parts within ourselves, but from causes and relations which are from without. No sensations of the body are to be gratified, but merely the sensation of the mind. However, that sensation of the mind always tends to some action of the body, and is to be gratified by certain actions which naturally arise out of the passion. Passion is confined to no one object; almost every object can excite passion; and while that passion lasts, the object that first produced it still continues to be the object.

Passions are instinct: they never improve. They are a union of two principles,—a certain internal impulse, producing actions which have concern in, or are connected with, a sensitive body, or which produce effects that are ruled or guided by our sensations. If they would seem to improve, it is only by encouraging them as we would encourage an appetite of any kind: but their improvement is only in a greater frequency, or repetition, especially in those the indulgence of which does not impair the animal powers.

Nature has not only given natural appetites, or internal impressions for such and such actions, to animals, and an uneasiness while under the impression, which peculiarity of uneasiness is the appetite itself, but has added a pleasure in the actions of removing the uneasiness, or gratifying the appetite; for example, in eating, in the propagation of the species, &c. But animals feel uneasiness when the bladder or rectum is full, and have no peculiar pleasure in getting rid of the uneasiness, further than arises from the cessation of uneasiness.

On Instinct.

Whatever impulse of action we have which does not arise from the knowledge of the event, or from a motive, is 'instinct;' and whatever action arises from an intention, is 'reason.'

The instinctive principle is probably nearly the same in all animals whose wants and consequent actions are nearly the same; and when one animal appears to have more extensive principles of this kind than another, it is because it has a greater scope of action, and of course attended with more variety.

I shall not instance any of the more imperfect animals [in illustration of instinct], but take the bird and the quadruped. I can conceive that a parrot and a crow have a greater extent of instinctive principles, leading to a greater variety and more neatness in their operations, than a cuckoo or a partridge has. I conceive that monkeys have more extensive instinctive principles than dogs, and dogs more extensive than sheep. And if man could lay aside acting from reasoning, his instinctive principles would be more extensive than any: but the actions arising from instinct are so heightened and made so much more perfect, that the instinctive actions appear, even to the mind of the persons themselves, to be wholly the result of reason. In crows, where the instinctive principle is pretty well marked, their actions come near to those of the human, [there] being no difference in the action excepting the human varying it a little more according to circumstances.

Thus a rook builds its nest according to the instinctive principle of the animal, and for this purpose breaks off branches of the trees on or near which it builds: it also gathers sticks on the ground near the nest: but the curious thing is their stealing from one another. Thus a neighbouring rook shall steal the sticks of another: they shall observe the motions of each other, and, when opportunity serves, they immediately become thieves.

It is curious to see how instinctive principles arise. When we see only the effect, and not the immediate cause, it appears wonderful; but, when we can trace them, they do not so much surprise us. The immediate cause of the bees' instinctive principles is not all laid open to us. It is curious to see the young duck run into the water the moment it sees it.

When two instinctive principles oppose one another in two different animals, it is curious to see the conflict. A hen, for instance, with duck-chickens, seeing them run into the water, is unhappy; and a duck with young hen-chickens, invites her brood into that element, while the chickens are running round the side of the water.

Instinct is in most respects similar to general principles in arts and sciences; for neither instinct nor general principles will apply equally to all cases, with which they have an immediate connexion. Instinctive principles are not fitted for, nor take notice of, contingencies; nor do general principles. A bird, when it builds its nest in a tree, does not consider accidents; and therefore does not guard against them. A man who lays down a general plan, and does not see the variations or deviations that should take place in it, and therefore does not guard against or provide for them, is acting like a bird. The bird, being wholly ruled by instinct, does not alter its plan (if it could be called one); but the man's, being a principle in his mind, he can and does vary from his original plan. However, this is not always the case; for general principles to many are such as that they cannot alter [their plans] even to meet contingencies; therefore their case is very similar to instinct.

Animals I believe have the power of repeating actions, which at first are accidental, but which give them pleasure; and, of course, of avoiding such as give them pain: and probably that is the utmost extent of the animal powers below the human, independently of instinct. The extent of these principles in any class of animals bespeaks their superiority over the others, and gives them a greater facility to learn.

A kitten plays with a ball from finding that it moves, and because that motion gives delight, from being similar to life in an animal.

I can conceive a monkey to be delighted with the effects of action; such as throwing things down, being pleased with seeing them fall: and the monkey having a greater variety of such amusements, this gives him a superiority over other animals, and brings him nearer to the human species in the state of childhood, before the consequences of actions can be considered.

Than that animals have reason, nothing can be more clear; for all animals can go mad; by which they lose all instinctive and acquired properties of the mind.

Loose 'Notes and Queries' on Imitation and Custom.

Imitation is so much a principle in Man that it distinguishes families, towns, and nations. Imitation in manner is caught by the sight; and as a proof of this, let us observe that a blind man has not the manner or gait or mode of walking that a man has that sees.

Because we do turn the optic nerves to objects most commonly, is no proof that it is not done by custom; for as the most distinct object is painted nowhere else, custom finds out that proper place. It would be contradictory to the rule of sensation to say that we would not turn the most sensible part to objects that we choose to be sensible of.

Closing our eyes when a cannon is fired arises from custom; for we do not do so when it is at a distance; nor would we do it at all, if we did not know there was a flash: a child does not do it.

Every thing that gives pleasure at first, lessens by practice; and every thing that gives pain, becomes more easy.

Do not all the sympathies that regard external objects, and are the principal causes of our moral sentiments, arise from custom? If we see a person comb his head, our head itches all over, and we cannot help scratching it [?].

We often do not know how to choose the same kind of thing, among a variety; but if we were sure of the right one, which [certainty] is acquired by custom, we should not be at a loss.

The belief of futurity is from custom. It arises from the repetition of events that arise naturally out of apparent causes, and which are every day showing themselves.

Miscellaneous Notes and Apothegms.

Ambition is a species of vanity: it is wishing or aiming at something beyond its powers.

There never was a man that wanted to be a great man ever was a great man[1].

Great men have endeavoured always to do some great action that seemed to tend to some great good; and the effect made them great. Wanting to be great is vanity without the power.

In the first, the person himself is not the object; or, if he be, he is only the secondary one: in the second, it is the person himself is the object, and the thing [to be done] is only the secondary.

Never take a gentleman [fine gentleman, or coxcomb, interpolates Mr. Clift] as a pupil in physic; for, depend upon it, it is not simple curiosity, it is himself that is the object of his attention: and, whatever knowledge he may acquire, is only to employ upon himself, or tease others: he becomes his own patient ever after.

Obligations rendered between equals have an equal value put upon them by both sides; and that is the value of the thing. Obligations conferred by an inferior on a superior enhances the value, not according to the value of the thing itself, but according to the superiority of him that takes it. This increases the [gift's] value in the giver's eye; while, on the other hand, the receiver only values it according to the [degree of the] giver; and even does not put the true value upon it; and not the same value that he would have put upon it if he had received it from an equal. This principle is the reason why inferiors blame so much the ingratitude of the great.

The degree of estimation in which any profession is held, becomes the standard of the estimation in which the professors hold themselves.

[1] [No man ever was a great man who wanted to be one.] Here Hunter shows his appreciation of the 'unconscious' element in true greatness.

It is uncomfortable to be employed in anything where the employer is more interested than the employed. This is the case with physic and the law; but more with the first; for, although it is the interest of every medical gentleman to attend to his patient, yet he can seldom give that satisfaction he could wish.

Medical men are always very ready to suppose disease, but are never ready to doubt.

It is much more pardonable to fall into an error than to follow an error.

Speaking truth is no natural propensity; it is only relating occurrences that have struck our senses, and are therefore more lively in our imaginations than anything we can feign. Besides, by law or by association, we have made it bad in a man to lie, because we found it productive of evil to those that choose to speak the truth.

When a man gives up anything, he has either a weak mind, or no fertility of genius.

It requires a great deal of courage in a man to continue poor while it is in his power to get rich[1].

Accusing Mr. Fox of having debauched the minds of most of the young men of fashion in this kingdom, I was answered, that he was liked by them all: I made reply, that they were similar in that respect to the women; for they could not help having a fondness for the man that had seduced them.

Mr. Burke's speeches put one in mind of a shrub full of flowers, which is pretty while viewed; but, strip it of its flowers, and it will hardly be taken notice of.

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[1] [Hunter must have penned this from personal consciousness. He might have died rich, if he had devoted his powers to the growth of his own fortune, instead of to the progress of science: he preferred to die poor, and to leave to his profession and the world a museum unrivalled in its teachings of the principles of medicine and surgery.]

OBSERVATIONS ON PALÆONTOLOGY.

Lectures explanatory of Hunter's Manuscript Essay 'On Extraneous Fossils,' and Introductory to the Hunterian Course 'On Fossil Remains,' delivered in the Theatre of the Royal College of Surgeons of England, in 1855. *By* Professor Owen, *F.R.S.*

Lecture I.

March 6th, 1855.

Mr. President and Gentlemen,—I propose to devote the present Course of Lectures to the illustration of the Hunterian Specimens of Fossil Organic Remains. The Palæontological is, in fact, now the only department of the Museum which has not been systematically elucidated in this theatre, to the extent, at least, of the time and ability at my command to devote to the fulfilment of the responsible and honourable duties which you have been pleased to confide to me.

Nor, remote as the subject of Fossils may seem from their aims to my purely anatomical and professional auditory, will it be found to be without the connexion which Hunter believed, and the philosophical surgeon will find it to have with the fundamental principles of medicine and surgery.

Anatomy, or the scrutiny of animal structures, may be pursued—irrespective of the various mechanical methods of investigation—in different ways and with different views.

An animal may be anatomized in order to a knowledge of its structure, absolutely, without reference to any other animal; the species being regarded as standing alone in creation, unconnected and uncompared with any other being or series of beings. The knowledge so acquired may, from the very limitation of the field of inquiry, be most accurate and most minute: it will be most valuable in its application to the cure of the diseases and repair of the injuries of such single species or subject. Such, *e. g.*, is 'Anthropotomy,' or the anatomy of the human subject; and 'Hippotomy,' or the anatomy of the veterinary surgeon's principal patient. The 'Anatome Testudinis Europææ,' fol. 1819, of Bojanus, and the 'Traité Anatomique de la Chenille du Saule,' 4to, 1762, of Lyonnet, are unsurpassed examples of this monographical species of anatomical science.

But the anatomist may apply himself to a particular organ instead of a particular species; and may trace the modifications of such organ as far it can be determined to exist in the animal kingdom: in which quest, if begun, as anatomy is usually entered upon, by the human subject, he would, with most organs, find them gradually losing some feature of essential complexity, and becoming reduced to a more and more simple condition.

This kind or way of anatomy occupied a great proportion of John Hunter's time. He thus, so far as opportunities presented themselves, or could be availed of, followed out organ after organ, until he had embraced the whole scheme of organs in the most complicated organism; and, having so traced down the simplifying modifications presented by the animals as they progressively departed from the perfection of the human type, he then assembled the evidences of his labours, reversed the order in which they had been investigated, and beginning with the simplest form which he had detected of each given organ, placed after it, in succession, the progressively more complex forms of the same organ, the series culminating, in most cases, with that which exists in the human body. Having thus laboriously obtained his knowledge and his material evidences of the modifications of particular organs analytically, Hunter strove to impart the higher conclusions deducible from those evidences by presenting them in the synthetical order requisite for such generalizations; as in the arrangement which governs the disposition of the Physiological Collection in the Museum.

A third kind of anatomy necessarily follows the synthetical route: it is that which takes the embryo of a particular species for its subject; and, starting from the moment of impregnation, or, perhaps, with a preliminary research into the progressive formation of the impregnating principle and its nidus, or material for operation—the development, viz., of the spermatozoid and the ovum—then proceeds to follow out the consequences of their mysterious union and mutual reaction. In this way each organ is traced step by step in its evolution, until it attains the condition suitable for the life-work of the adult parents of the embryo under investigation. And when the subject selected for the inquiry happens to have belonged to one of the higher classes of animals, it has been found that the gradational series of changes which a given organ presents in the course of its development, resemble in some degree the chief steps or links in the series of mature organs derived from different species according to the second mode of inquiry.

A fourth way of anatomy is that which, beginning with an investigation of the structure of an animal in its totality, in order to understand how the form or condition of one organ is related and necessitated by its functional connexions with another, the coordination being adapted to the peculiar habits and mode of life of that species, does not stop at that one species, but has for its main end, the comparison of those associated modifications, interdependencies, or correlations of organs in all the different species and classes of animals.

The results of this way of anatomical research are made known according to the class of animals inquired into—as, *e. g.*, the anatomy of Fishes, the anatomy of Birds, &c., in contradistinction to the method which governs the above-cited arrangement of Hunter's Physiological Series of specimens, and the order of the descriptions in the 'Leçons d'Anatomie Comparée' of Cuvier.

But, in his general collection, Hunter illustrates all the three ways in which the anatomy of animals may be broadly and philosophically followed out.

There is the series of organs in their mature state, traced from their simplest to their most complex conditions, as in the first division of the Physiological Series.

There is a series of the progressive changes or stages in the development of each organ in the embryo and fœtus of different species, as, *e. g.*, in the second division of the same great Series.

There is, thirdly, a series of entire animals, occasionally dissected to show the general collocation of their organs, and arranged, as in the Physiological Series, in the ascending order, commencing with the more simple forms and proceeding gradationally to the Mammalia and to Man.

The Council of this College has done me the honour to confide to me the making of the Catalogues of these several exemplifications of animal structures, and of the methods by which those structures may be studied. And those Catalogues have been completed and published, with one small exception relating to the Vertebrated province of the series arranged according to the classes of animals.

In the performance of another department of expository duties—those which I have the privilege to fulfil in this theatre—I have, in accordance with the terms of my appointment, and the aim which the legislature had in view in attaching a Hunterian Professorship to the acceptance by the College of the Hunterian Collection, endeavoured to make the successive courses of lectures subservient to the elucidation, not only of the science of Comparative Anatomy, and of the several methods by which it may be studied, but of the Hunterian series of specimens by which those several departments of zootomical science are illustrated in the Museum. Thus the different systems and organs have been treated of, tracing their modifications from the most simple to the most complex forms, agreeably with the order of arrangement of the first division of the Hunterian Physiological Series, in the lectures which occupied the first five years of my office as Hunterian Professor.

Afterwards I made the generation of animals and the development of the different organs, the subject of two Courses of Lectures, and illustrated them by the preparations of the second division of the Hunterian Physiological Series.

In next entering upon the illustration of the extensive collection of Comparative Osteology, I felt it to be my duty to go as deeply and thoroughly as my powers and leisure would enable me, into the question which the two great luminaries of the School of Anatomy and Natural History of France, Cuvier and Geoffroy St. Hilaire, had left undecided, in the ardent discussions which agitated the close of their respective careers: I allude to the subject, or line of zootomical research, which is commonly called abroad 'Philosophical Anatomy,' but which is, in truth, 'Homological Anatomy,' or that which aims at determining the strictly answerable parts and organs in different species, and which expresses the successful results of such comparisons, by giving to the demonstrably answerable parts and organs in different animals the same name. The aggregate results of this fifth way of anatomical research, exemplify the extent to which the term 'Unity of Organization' can be applied to the animal kingdom, and they show the kind and amount of truth which was partly appreciated by Goethe, Oken, Spix, and Carus, but was obscured by the figurative and commonly exaggerated expressions by which those gifted and accomplished intellects endeavoured to express a great and pregnant truth of which they had obtained different partial views.

After this Session, as I have never deemed it the privilege of your Hunterian Professor to repose upon the repetition of the same annual course of lectures, with the mere addition of the chief discoveries of the preceding year, I entered upon the study of the Hunterian Series of entire animals of which the Catalogue of the Invertebrated Classes has been published, and arranged the facts of comparative anatomy according to their correlations in subserviency to the habits of particular species.

In the session of last year I concluded the series of lectures in which the animal organization was treated of according to the classes of animals, beginning with the lowest and ending with the highest.

I still look forward to the kind and liberal indulgence of the Council of this College for the license, if life and health be spared, to reduce and make public the manifold materials which I have accumulated for these several courses of Hunterian Lectures.

It might well be thought that the ways in which the philosophical investigation of animal organization may be carried out, were exhausted in the monographical or anthropotomical, organical, embryological, zoological and homological methods just defined. But there is yet another method.

I do not allude to the microscopical mode of research: that is only a more refined method of the scrutiny of animal parts, and has now become an essential one, whether we investigate the structure of an organ or of an organism,—whether we are tracing the modifications of the heart, *e. g.*, in a succession of animals, or the combination of the pulsatile and other organs in one minute animal. It is true, that, as the high powers of the microscope can only be brought to bear on minute particles, they have been for the most part applied to the constituent parts of an organ, the tissues, as they are termed, whence the term 'Histology,' now commonly applied to microscopic anatomy.

But this more refined mode of research, so successfully and systematically pursued within these walls by my esteemed colleague, Professor Quekett, must be superadded to the ordinary procedures of dissection, whether we pursue an absolute anatomy of one species, or enter upon the anatomy of animals generally, by either of the routes, organically, embryologically, or zoologically, which I have just defined. Histology is a minuter mode of anatomizing, but is not a distinct kind of comparative inquiry. Reckoning it, however, as a sixth kind, what, then, it may be asked, is the seventh way in which the highest generalizations in anatomical science may be aimed at? My reply is, by pursuing investigations beyond the animals that *are*, to those that *have been*.

Let us assume it to be a truth that the actually existing animal creation forms but a small proportion of that which has lived and energized during former periods on this planet.

Each year brings more evidence of this truth, and narrows the proportion which the present zoological series bears to the past,—the living to the extinct creations!

If all the successive races of beings that have peopled, at successive periods, the same globe be the work of one and the same Creative force, can we hope to gain a due insight into the laws according to which that force has operated in their introduction, by limiting our investigations to the residuary groups of beings that characterize the present epoch? As well might we flatter ourselves that we had an adequate notion of anatomy from the results of assiduous anthropotomy, as that we could arrive at the highest facts in the philosophy of animal structures without having first observed and compared all the structures at our command.

The soundness of the Baconian principles of induction are too firmly established, too universally recognized, too brightly exemplified by the glorious results of philosophical inquiry conducted in subservience to them, to permit us for a moment to suppose that they can be set aside without defeat and loss in the high, if not highest, exercise of the truth-seeking intellect, viz. that which has the laws of the animal organization for its object.

John Hunter had not neglected the field of anatomical inquiry presented by fossil organic remains.

He lived to publish little respecting them. The scientific world probably first became cognizant of the fact that he had paid any attention at all to them, when Hunter communicated to the Royal Society of London, in 1793, his paper "On the Fossil Bones presented to that Society by His Most Serene Highness the Margrave of Anspach."

That paper was printed in the 84th volume of the 'Philosophical Transactions,' in 1794, as 'by the late John Hunter, Esq., F.R.S.,' that great man having in the interval been suddenly removed, at the age of sixty-five, under the distressing circumstances so well known, from the scene of his surprising and exemplary labours.

Those men accustomed to think, who heard or read that paper, would recognize in it the mind of the great master. It is characterized by the same broad views and acute insight into the phenomena under review, by the same unexpected illustrations which only a wide embrace of facts could have suggested, by the same bold excursions into fields stretching away far beyond the immediate subject of the memoir, which peculiarly mark all the papers from Hunter's pen.

But the memoir to which I refer, would be far from impressing an adequate conception of the extent to which Hunter had pushed his examination and collection of fossil organic remains. A few private friends might be aware of his zeal and interest in this, at that time, neglected or scarce known field of anatomical inquiry; and they might have marvelled at the cause of such zeal in the acquisition of the 'extraneous minerals,' or 'fossils,' which seemed so little raised in importance above the 'native minerals' with which they were then commonly associated.

In those letters which, since Jenner's death, have come to light, addressed to the favourite pupil by the revered teacher—both names now alike immortal!—and which letters are introduced into the life of John Hunter prefixed to Palmer's edition of his works[1], scarcely one of them omits a recommendation to Jenner to secure for his correspondent whatever fossil remains might fall in his way.

In regard to the paper in the 'Philosophical Transactions,' if hastily

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[1] [1837, 8vo, Longmans.]

read, that single posthumous published contribution by Hunter to Palæontology, might fail to leave an adequate impression of the degree in which Hunter knew and appreciated the value of fossil remains; and accordingly we find that Cuvier, usually so equal and exact in his notice of the labours of his forerunners, characterizes the memoir on fossil bones by "le celèbre chirurgien Anglais," as one "qui n'a que leur analyse chimique pour objet,"—as one that had only the chemical analysis of the fossils for its object.

It is true, that in this paper Hunter incidentally introduces the results of a very extensive series of such chemical investigations, and he describes the different conditions in which the original animal matter may be found in petrified bones, teeth, and shells more truly and definitely than it has since been done by any modern Palæontologist, their attention having been almost exclusively paid to the anatomical and zoological characters of fossil remains.

Thus he remarks,—"All operations respecting the growth or decomposition of animal and vegetable substances go on more readily on the surface of the earth than in it; the air is most probably the great agent in decomposition and combination, and also a certain degree of heat. Thus the deeper we go into the earth, we find the fewer changes going on; and there is probably a certain depth where no change of any kind can possibly take place. The operation of vegetation will not go on at a certain depth, but at this very depth a decomposition can take place, for the seed dies, and in time decays; but at a still greater depth, the seed retains its life for ages, and when brought near enough to the surface for vegetation, it grows. Something similar to this takes place with respect to extraneous fossils; for although a piece of wood or bone is dead, when so situated as to be fossilized, yet they are sound and free from decomposition, and the depth, joined with the matter in which they are often found, as stone, clay, &c., preserves them from putrefaction, and their dissolution requires thousands of years to complete it; probably they may be under the same circumstances as in a vacuum; the heat in such situations is uniform, probably in common about 52° or 53°, and in the colder regions they are still longer preserved.

"I believe it is generally understood that in extraneous fossils the animal part is destroyed; but I find that this is not the case in any I have met with.

"Shells, and bones of fish, most probably have the least in quantity, having been longest in that state, otherwise they should have the most; for the harder and more compact the earth, the better is the animal part preserved; which is an argument in proof of their having been the longest in a fossil state. From experiment and observation, the animal part is not allowed to putrefy, it appears only to be dissolved into a kind of mucus, and can be discovered by dissolving the earth in an acid; when a shell is treated in this way, the animal substance is not fibrous or laminated, as in the recent shell, but without tenacity, and can be washed off like wet dust; in some, however, it has a slight appearance of flakes.

"In the shark's tooth, or glosso-petra, the enamel is composed of animal substance and calcareous earth, and is nearly in the same quantity as in the recent; but the central part of the tooth has its animal substance in the state of mucus interspersed in the calcareous matter.

"In the fossil bones of sea animals, as the vertebræ of the whale, the animal part is in large quantity, and in two states; the one having some tenacity, but the other like wet dust: but in some of the harder bones it is more firm.

"In the fossil bones of land animals, and those which inhabit the waters, as the sea-horse, otter, crocodile, and turtle, the animal part is in considerable quantity. In the stag's horns dug up in Great Britain and Ireland, when the earth is dissolved, the animal part is in considerable quantity, and very firm. The same observations apply to the fossil bones of the elephant found in England, Siberia, and other parts of the globe; also those of the ox kind; but more particularly to their teeth, especially those from the lakes in America, in which the animal part has suffered very little; the inhabitants find little difference in the ivory of such tusks from the recent, but its having a yellow stain; the cold may probably assist in their preservation.

"The state of preservation will vary according to the substance in which they have been preserved; in peat and clay I think the most; however, there appears in general a species of dissolution; for the animal substance, although tolerably firm, in a heat a little above 100° becomes a thickish mucus, like dissolved gum, while a portion from the external surface is reduced to the state of wet dust.

"In encrusted bones, the quantity of animal substance is very different in different bones. In those from Gibraltar there is very little; it in part retains its tenacity, and is transparent, but the superficial part dissolves into mucus.

"Those from Dalmatia give similar results when examined in this way.

"Those from Germany, especially the harder bones and teeth, seem to contain all the animal substance natural to them: they differ however among themselves in this respect.

"The bones of land animals have their calcareous earth united with the phosphoric acid instead of the aërial, and, I believe, retain it when fossilized, nearly in proportion to the quantity of animal matter they contain.

"The mode by which I judge of this, is by the quantity of effervescence; when fossil bones are put into the muriatic acid it is not nearly so great as when a shell is put into it, but it is more in some, although not in all, than when a recent bone is treated in this way, and this I think diminishes in proportion to the quantity of animal substance they retain; as a proof of this, those fossil bones which contain a small portion of animal matter, produce in an acid the greatest effervescence when the surface is acted on, and very little when the centre is affected by it; however, this may be accounted for by the parts which have lost their phosphoric acid, and acquired the aërial [carbonic acid], being easiest of solution in the marine acid, and therefore dissolved first, and the aërial acid let loose.

"In some bones of the whale the effervescence is very great; in the Dalmatia and Gibraltar bones it is less; and in those the subject of the present paper it is very little, since they contain by much the largest proportion of animal substance[1]."

The results of these varied chemical experiments would have afforded the most convincing answer to the objections so rife, in the century or two which preceded Hunter, to any scientific deductions from fossil remains, because, as it was contended, they were mere sportive evidences of the plastic force of nature,—an idea entertained by the great anatomist Fallopius, amongst others, who maintained that certain tusks of elephants dug up in his time, in Apulia, were mere earthy concretions. Had he known that those tusks contained a quantity of the very gelatinous substance which formed the basis of the human skeleton, and that the earthy matter of the supposed concretion was the same peculiar combination of lime with phosphoric acid which hardens the human bones and teeth, the learned Professor of Padua would doubtless have been led to reconsider his assent to the current delusion of his day, as to the nature of the fossils submitted to him.

The observations on the chemical conditions of fossil bones, form, however, but a small part of Hunter's paper published in the 'Philosophical Transactions.'

He compares the fossils which are the subject of his text with the osteology of recent animals; determines their generic affinity to the bear; and shows not only that they differ from any of the species with which he was able to compare them, but also that the fossils differed from each other. For reasons which Hunter assigns, from having

[1] [Philosophical Transactions. vol. lxxxiv. 1794.]

observed the differences of shape which the skull of a carnivorous animal presents at different periods of life, he expresses himself with philosophic caution on the nature and value of those differences. "How far the fossils are of the same species among themselves, I cannot say. The heads differ in shape from each other; they are upon the whole much longer for their breadth than in any carnivorous animal I know of. They also differ from the present white bear, which, as far as I have seen, has a common proportional breadth. It is supposed, indeed, that the heads of the present white bear differ from each other. But the truth of this assertion I have not seen heads enough of that animal to determine." As, at present, my object is to illustrate the spirit in which Hunter had entered upon this most interesting application of his anatomical science, I will merely request attention to the last-quoted remark of Hunter, as explanatory of the reasons which led him to begin and zealously carry on his accumulations of comparative osteology, and the absolute necessity of possessing skulls of the same species of the different sexes and at different ages, in order to fix our determination of problematic fossils on a secure basis.

"Some of the fossil skulls," Hunter proceeds to remark, "when compared with the recent white bear, would seem to have belonged to an animal twice its size. But the varieties among the fossil bear's bones," he affirms, "is not less than between these and the recent." The truth of this remark is exemplified by the names *Ursus spelæus*, *Ursus bombifrons*, and *Ursus priscus*, applied by Cuvier and later palæontologists to the fossils described and figured by Hunter in the memoir of 1793, from which I quote: in which it will be plainly seen that the observed difference, due to age, in the shape of the skull of one and the same species, is adduced as only one of the circumstances to be taken into consideration in comparing recent and fossil crania, and that Hunter by no means asserts, as Cuvier affirms[1], "that the differences which he had detected between the fossil and recent skulls, and between the different fossil skulls of the cave bears, are of the same nature and degree."

Having concluded his comparative remarks, and shown that the fossils differed from the recent species known to him, and also differed from each other, Hunter next briefly alludes to the different situations and climates of the globe, to which animals are more or less confined. The terms in which he expresses his general idea on this important topic are peculiarly characteristic of his style and mode of thought. "Bones of animals under circumstances so similar [*i.e.* as to their imbedding and fossilization], although in different parts of the globe, one would have

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[1] [Ossemens Fossiles, 8vo. ed. 1836, tom. vii. p. 236.]

naturally supposed to consist chiefly of those of one class or order in each place, one principle acting in such places." The principle here alluded to is the grand result of the extensive zoological researches which have since established it, under the term of the 'Geographical distribution of animals.' Hunter's first glimpse of it seems to have begot as great a difficulty in its expression as that of the resemblance of the phases of embryonic life to the series of inferior forms of animal species, which he was the first to enunciate [p. 203]. But, in both cases, he has recourse to explanations of his meaning, and tries to deliver himself of the same idea in other forms of words; thus, after the first enunciation of a supposed localization of particular classes or orders of animals, "according to one principle," Hunter next proceeds to say:—

"In considering animals respecting their situation upon the globe, there are many which are peculiar to particular climates; others that are less confined; and others again which, probably, move over the whole extent of the sea, as the shark, porpoise- and whale-tribes; while many shell-fish must be confined to one spot."

And here, by the way, it is interesting to find that the migrations of the marine animals to which Hunter alludes, as 'probable' in the species recited, are precisely those regarding which zoologists of the present day still entertain some difference of opinion; but all seem now agreed that certain *Cetacea* of the southern hemisphere differ specifically from those of the northern seas. As to the application of the law of Geographical distribution of animals to fossil remains, Hunter's philosophical supposition has been abundantly confirmed, by the marsupial character, *e. g.*, of the fossil mammalia from the caves and tertiary deposits in Australia —the land of kangaroos; and by the gigantic sloths, armadillos and anteaters, whose remains occur "under circumstances so similar" in South America, to which tract of dry land true anteaters (*Myrmecophagæ*), armadillos, and sloths are now, and seem ever to have been, confined.

Hunter, in the memoir from which I quote, next proceeds to touch upon the nature of the evidences by which fossil remains might elucidate the changes of temperature to which different parts of the earth may have been subject at different epochs; and he points out more distinctly, and with more detail, the evidence which extraneous fossils afford, respecting the alternations of exposure and submersion, or of dry land and sea, to which different parts of the earth have been subject at different epochs.

"From a succession of such shiftings of the situation of the sea, we may," he writes, "have a stratum of marine extraneous fossils, one of earth, mixed probably with vegetables and bones of land animals, a stratum of terrestrial extraneous fossils, then one of marine productions;

but from the sea carrying its inhabitants along with it, wherever there are those of land animals there will also be a mixture of marine ones; and from the sea commonly remaining thousands of years in nearly the same situation, we have marine fossils unmixed with any others[1]."

The importance of the study of fossil remains in the elucidation of the nature of the changes to which the earth's surface has been subject, above dwelt on by Hunter, has subsequently been abundantly confirmed, and placed in very strong light by the researches more particularly of Cuvier and Brongniart on the structure of the tertiary deposits occupying what is called the 'Paris Basin,' and on the fossils, and more especially those of the Montmartre quarries, which have rendered that locality so famous. By the light of these fossils Cuvier was enabled to refer the succession of the eocene strata near Paris to several alternations of marine and freshwater deposits.

One other characteristic of the paper in the 'Philosophical Transactions,' and I have done with that published evidence of Hunter as a Palæontologist,—the frequent, and for that date, bold allusions therein made to the 'thousands of years' required for particular operations, or the lapse of time appreciated both as regards geological phenomena and the fossilization of animal remains.

"Although," writes Hunter, "a piece of wood or bone is dead when so situated as to be fossilized, yet they are sound and free from decomposition." How true that remark is, the microscope has since abundantly demonstrated. The spiral vessels of plants, the tubular structure of teeth, are as characteristic in the completely silicified as in the recent specimens. "The depth," Hunter proceeds, "joined with the matter in which they are often found, as stone, clay, &c., preserves them from putrefaction, and their dissolution requires thousands of years to complete it." It is plain, from these allusions, that Hunter appreciated the necessity for an ample allowance of past time, in order to account philosophically for the geological and palæontological operations which the subject of this paper for the Royal Society led him to investigate and reflect upon.

Before entering upon the next and more important evidence of the extent and spirit of Hunter's researches into the zoology and anatomy of extinct animals, and the associated phenomena elucidating the past history of our globe, I must premise the traditional history of that evidence, as I received it from my predecessor Mr. Clift.

Hunter, with his usual indefatigability, followed up his first memoir, on the fossil bones submitted to him by the Maregrave of Anspach, by

[1] [Phil. Trans. *tom. cit.*]

a second memoir, summing up the conclusions which he had deduced from his study of 'Extraneous Fossils' in general. Part of this memoir Mr. Clift wrote out under the dictation of Hunter[1], chiefly from separate sheets or slips of paper, on which Hunter had doubtless, from time to time, noted down the observations he had made and the ideas as they arose in his mind, out of those observations. This constructive intellectual work was performed in the evening, Hunter having previously taken his usual hour's sleep after dinner—a sacred hour, in which he was only to be disturbed in matters of the utmost emergency. Thus refreshed, the philosopher returned to his study, and passed the hours from eight o'clock to midnight in the business of writing or dictation. The penning of the paper 'On Extraneous Fossils and their relations,' was one of the first of Mr. Clift's evening-labours after he joined Mr. Hunter's household. This manuscript completed, Hunter took it, corrected it; and, as Mr. Clift believed, communicated it to the Royal Society[2].

What followed thereupon Mr. Clift subsequently heard from Sir Everard Home. The attention of the Secretaries or Council of the Royal Society had been called, by some of the Fellows, to the expressions in the first paper, on the "thousands of years" required for such and such geological phenomena; and, in the second memoir, the Secretaries found that a chronology of the earth, widely different from the usually accepted one, was more directly and emphatically affirmed by the author, as essential to the rational comprehension of the phenomena he treated of, while, at the same time, the adequacy of the chief or sole geological dynamic, at that time recognized, viz. the Mosaic Deluge, to account for the presence of marine fossils on land was called in question. Considerations for the repute and interests of the author himself may have swayed his advisers in the recommendation to him to submit the MS. to a geological friend, before finally sending it in for formal acceptance and perusal before the Society. Major Rennell, author of some papers in the 'Philosophical Transactions' on 'Tides and Currents,' and other geographical subjects, undertook the delicate task of submitting to Hunter the misgivings of the authorities mainly responsible for the publications of the Royal Society. He did it in these words: "This leads me to remark that, in page 3, you have used the term 'many thousand centuries,' which brings us almost to the *yogues* of the Hindoos. Now, although I have no quarrel with any

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[1] [It is not probable that the other amanuensis was Mr. William Bell, as is affirmed in the preface to the 4th ed. of this MS., recently published by the Royal College of Surgeons: he went to Sumatra in 1789, and died there in 1792.]

[2] [I find no record of its formal presentation to the Society, in the Minutes of Council of that period (1793–94).]

opinions relating to the antiquity of the globe, yet there are a description of persons very numerous and very respectable in every point but their pardonable superstitions, who will dislike any mention of a specific period that ascends beyond 6000 years: I would, therefore, with submission, qualify the expression by many thousand *years*, instead of *centuries*." Hunter would not modify his statements, and he withdrew the paper.

If this be the correct history of what took place in reference to probably the last, and certainly most interesting, of Hunter's writings —and I give it literally as I received it, and as I know Mr. Clift implicitly believed it—what a striking illustration it affords of the immense progress in geological science which has been achieved between the date of Hunter's demise (1793) and the publication of Buckland's 'Bridgewater Treatise,' 1836! What a cheering evidence it affords of the influence of Natural Truth on the receptive mental faculties of mankind; and how remarkably it exemplifies the degree in which John Hunter had surpassed, not merely his own age, but the élite of it, viz. certain of his scientific contemporaries and fellow-labourers in the Society expressly founded for the promotion of Natural Knowledge!

And now I can imagine the eager inquiries of my geological hearers as to the fate of this traditional contribution, by the greatest physiologist of his time, to their favourite and fascinating science.

With equal pleasure I can assure them that this precious manuscript exists.

After the demise of the first Sir Everard Home, it was transmitted by his son, Captain Sir E. Home, R.N., to this College: the minute recording its reception bears date April 2nd, 1839.

This manuscript, entitled "On Extraneous Fossils," displays the characteristic plain legible quality of the well-known handwriting of the amanuensis,—pale, indeed, and faint by lapse of time, and with a boyish stiffness of character due to the early period of life when Mr. Clift penned it, under the dictation of his venerated master. Above all, and most important as stamping its authenticity, almost every page bears some correction or addition in the handwriting of John Hunter himself.

This manuscript, moreover, bears the unmistakeable characteristics of its author's style and mode of thought. It demands for its appreciation, if not its comprehension, some approach to the power of mental labour and application which governed its production. The attention of its readers and of my audience will not be excited, or their probable weariness relieved by any graces of style or artifices of rhetoric. Pure truth, the plain expression of the thoughts and conclusions to which his facts had led, are here, as in all Hunter's writings, the sole aim of the author.

What, however, it may be asked, were the data on which Hunter—

the last man to write upon a subject that he did not believe himself to have thoroughly investigated,—what were the grounds on which he had based a dissertation on the general subject of 'Extraneous Fossils?' The reply is given, most amply, by the collection of fossil remains which he had made at the date of its composition, which was close upon the period of his demise; most satisfactorily, by the systematic arrangement of that collection; by the juxtaposition, in some instances, of the recent analogue with the fossil, and by the evidence of his close attention to the subject in the Catalogue which he left of those arranged specimens of Palæontology. In this Catalogue, a greater proportion of the specimens bear names than in any other of Hunter's MS. Catalogues: such names, at least, as Hunter could obtain or determine in regard to them; the locality of the fossil being, likewise, in most instances recorded.

Having completed the descriptive Catalogues of the Vertebrate Fossils and a general survey and preliminary class-arrangement of the Invertebrate Fossils, I am enabled to state that the Hunterian specimens of fossil organic remains include, of those belonging to the classes *Mammalia* and *Aves*, 330[1]; *Reptilia* and *Pisces*, 351[2]; of *Invertebrated* classes, 2092; the total number being 2773[3].

The classification adopted by Hunter in his MS. Catalogue, with his posthumous manuscript on Extraneous Fossils, will appear in the general Preface to be appended to the final volume of the Catalogue now in course of preparation[4] [1855].

Meanwhile I propose, at our next meeting, in justice to Hunter, and

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[1] [The volume including the descriptions of these fossils was published in 1845.]

[2] [The volume including the descriptions of these fossils was published in 1854.]

[3] [The Editor of the edition of the Hunterian MS. on 'Extraneous Fossils,' hurriedly printed by the Council of the Royal College of Surgeons in December 1859, states, with characteristic stupidity and indifference to accuracy, "The number of Hunterian Fossils in the collection amounted to 415" (p. ii. pt. 1),—the precise numbers having been expressly recorded in the Prefaces to the printed Catalogues of 1845, 1854, and 1856.]

[4] [Having accepted the office of Superintendent of the Natural History Departments in the British Museum early in 1856, the Catalogue of the Fossils in the Hunterian Museum passed out of my responsibility and care, and the completion of the concluding volume was confided to Prof. Morris, F.G.S. In the preface to that volume, published at the latter part of 1856, no allusion is made to the Hunterian manuscript, which Mr. Clift had, in 1839, formally brought under the notice of the Council and Board of Curators, as an 'Introduction to the Catalogue of Hunter's Collection of Extraneous Fossils,' and which had been more emphatically brought to their attention by my lectures in March 1855. It was not until their attention had been for the third time called to this manuscript, by my request in October 1859, to append it to the present collection of Hunter's writings, that it was suddenly determined to print it without loss of time; and a reason assigned which will be found in the Appendix (C.).]

to avoid any chance of interrupting the attention to his chain of reasoning of some who may be present, and may be much better qualified to understand the subject than myself, to read the paper through without comment. In a subsequent Lecture I shall point out the statements and conclusions in which Hunter had been anticipated by previous writers. I shall next endeavour to show how far ulterior investigations may have confirmed or confuted any of his propositions; and lastly, I shall give a general or summary view of the chief principles of geological and palæontological science which have been determined since Hunter wrote on the subject.

Lecture II.

March 8th, 1855.

[The manuscript read on this day, in the Theatre of the Royal College of Surgeons, not having been printed, as I had recommended and hoped, with the concluding volume of the Catalogue of the Hunterian Fossils published by the Council of the College in the course of the following year, and three years having since elapsed, I concluded that the MS. might not, in the judgment of the Council, have been deemed of sufficient importance to be issued as a collegiate publication. I therefore wrote, on the 25th of October, 1859, a respectful request to the President and Council, to which the following answer was returned:—

"Royal College of Surgeons, London,
11th day of November, 1859.

"Sir,—In reply to your application to be allowed to have a copy made of the Hunterian manuscript on geology for publication in a volume you are preparing for the press, which will include a selection from other Hunterian manuscripts copied by Mr. Clift from the originals before they passed into the hands of Sir Everard Home, I am desired to acquaint you that the question of the publication by this College of the said paper, together with the other unpublished Hunterian manuscripts, is under consideration, and that the Council does not consider it advisable, pending such consideration, that the paper on geology should be published in the manner you propose.

"I am, Sir, your most obedient Servant,
"Edmund Belfour, Secretary."

"*Professor Owen, &c. &c.*"

The manuscript in question was thereupon sent to the printers, and was published in 4to, by the Council of the College, December 23rd, 1859. Reference will be made to this volume in the quotations cited in the next Lecture.]

Lecture III.

March 10th, 1855.

Mr. President and Gentlemen,—In fulfilment of the intention expressed in my first Lecture, in reference to the Hunterian manuscript which I read at our last meeting, I proceed to point out the principal propositions in it, which, now generally accepted as true, had been, though perhaps unknown to Hunter, enunciated more or less clearly before his time: I propose to show what propositions of his were new at the time when he penned them, and have been subsequently rediscovered. I believe I may be able to indicate some views of Hunter that are now novel, and being true, are direct additions to geological science: in a few instances I shall have to point out his mistakes; and more frequently to endeavour to throw light upon his obscurities of expression. Finally, I shall briefly allude to the guiding principles of geological and palæontological science that have been established since Hunter's time.

First, as to the title of Hunter's memoir "On Extraneous Fossils:"—

In Hunter's time the term 'fossil,' as a noun, was used in the same sense as that in which we now use the term 'mineral.' Thus Da Costa, in his 'Syllabus of a Course of Lectures on Fossils,' delivered in London in 1778, begins by stating that "Fossils are not organized bodies, nor have they seeds;" and twenty-one lectures are devoted to the various classes of these fossils, such as earths, clays, metals and semi-metals, which he terms 'Native Fossils;' the concluding six lectures are devoted to 'Extraneous Fossils,' or 'Parts of Animals and Vegetables found buried in the Earth.' These were called, before that time, 'Figured Fossils,'—a term indicative of the still lingering notion that they were of the same nature as ordinary minerals, but had assumed, by the operation of a plastic force of nature, the figures of parts of plants and animals.

"Extraneous Fossils," writes Hunter, "make one part of a class of preserved parts of vegetables and animals; and as most vegetables and many parts of a great variety of animals can either be preserved themselves, or make such impressions as mark the originals to be either vegetable or animal, which are lasting, we are at no loss to say what had been either vegetable or animal:—but for the understanding of which, it will be proper to take a general view of such preserved parts, and to give some of the principal leading facts to establish a principle respecting their preservation.

"As vegetables are formed only on the land, and are stationary, and as animals are formed both on the land and in the sea, also inhabiting both; and may be said to be stationary respecting the elements in which they live; and as they are all found in a fossil state now in the earth which is not covered by water, as if all had been originally formed there, it naturally leads us into an investigation of the operations that must have taken place on the surface of this globe; and which also, so far as the extraneous fossils go, leads to the formation of native or mineral fossils. But it is to be understood that this investigation has nothing to do with the original formation of the earth itself; for that must have been prior to the formation of the extraneous fossil, which has only a connexion with the changes on the surface; therefore, as in the fossils, our mode of reasoning on this subject may be termed retrograde; it is supposing from the state of the earth now, what must have taken place formerly; for we are obliged to take the facts, and guess at their cause; their history, prior to their discovery, being entirely unknown, and few relative circumstances, leading to it, being almost left wholly to conjecture; for we have few intermediate circumstances leading from one to the other; the distance of time between cause and effect is too long for observation, and history gives us but little assistance, hardly a hint.

"In this investigation we are obliged to search after the causes of operations from effects completely performed; but as these may be made out at some future period, their history becomes a kind of mark for future ages to judge by, and will be the means of correcting the errors we now naturally run into; all of which we should have been unable to consider, if we had not the preserved parts of sea-animals, each in a great degree explaining the other.

"The fossils of sea-animals inform us of the change of place in the waters, otherwise we could not have supposed it; just as we would trace the remains of former actions in any country by the monuments left, judging of past by present."

"As this is a subject connected with, or makes a part of, the Natural History of Vegetables and Animals, it has by me been occasionally one of my pursuits, with a view to match the fossil with the recent animal, and see how the present corresponded with the past; in which time I have, with the assistance of my friends, made a considerable collection[1], and have arranged them according to a system agreeing with the recent."—Pp. i & ii.

Hunter, in defining 'Extraneous Fossils,' does not limit them to 'Parts of Animals and Vegetables found buried in the earth,' but extends the term to 'impressions,' 'casts,' and 'moulds of such'—a class of evidences the value of which has subsequently been fully appreciated, and which has been found to include not only impressions made by the dead organisms, but those left by the footsteps of living animals, as well as

[1] [See p. 295.]

by operations of inorganic nature. It has become a distinct branch of the science of fossil remains, under the name of 'Ichnology'[1].

"Vegetables," he says, "are formed only on the land." By this Hunter probably meant that, whether they grew in an atmosphere of air or water, they grew on and from the earth; as the sea-weeds of our coast are attached by their discoid roots to rocks and stones, and the more obvious freshwater plants grow, also, from the bottom. There are, however, exceptions to this rule: a very large one—the floating 'Sargasso' of the Gulf-stream—had escaped the memory of Hunter; this sea-weed is generated and developed in the ocean, as freely, as independently of its bottom, as the whales and fishes that are born or brought forth free, and, as Hunter states, are 'formed in the sea.'

I would next request your attention to Hunter's idea of the proper end and limits of the study of geology and fossil remains:—"This investigation," he tells us, "has nothing to do with the original formation of the earth itself; but has only a connexion with the changes on its surface."

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[1] ["There are several circumstances under which impressions made on a part of the earth's surface, soft enough to admit them, may be preserved after the impressing body has perished. When a shell sinks into sand or mud, which in course of time becomes hardened into stone, and when the shell is removed by any solvent that may have filtered through the matrix, its place may become occupied by crystalline or other mineral matter, and the evidence of the shell be thus preserved by a cast, for which the cavity made by the shell has served as a mould. If the shell has sunk with its animal within it, the plastic matrix may enter the dwelling-chamber as far as the retracted soft parts will permit; and as these slowly melt away, their place may become occupied by crystallized deposits of any siliceous, calcareous, or other crystallizable matter that may have been held in solution by water percolating the matrix, and such crystalline deposit may receive and retain some colour from the soft parts of which it thus becomes a cast.

"Evidences of soft-bodied animals, such as *Actiniæ* and *Medusæ*, and of the excremental droppings of higher animals, have been thus preserved. Fossil remains, as they are called, of soft plants, such as sea-weeds, reeds, calamites, and the like, are usually casts in matrix made naturally after the plant itself has wholly perished.

"Even where the impressing force or body has been removed directly or shortly after it has made the pressure, evidence of it may be preserved. A superficial film of clay, tenacious enough to resist awhile the escape of a bubble of gas, may retain, when petrified, the circular trace left by the collapse of the burst vesicle. The lightning flash records its course by the vitrified tube it may have constructed out of the sandy particles melted in its swift passage through the earth. The hailstone, the ripple wave, the rain-drop, even the wind that bore it along and drove it slanting on the sand, have been registered in casts of the cavities which they originally made on the soft sea-beach; and the evidence of these and other meteoric actions, so written on imperishable stone, have come down to us from times incalculably remote. Every form of animal life that, writhing, crawling, walking, running, hopping, or leaping, could leave a track, depression, or footprint behind it, might thereby leave similar lasting evidence of its existence, and also to some extent of its nature."—Owen's 'Palæontology,' 8vo, 1860, p. 152.]

Prior to Hunter's time the main business of geology seems to have been to discover the mode in which the terraqueous globe originated, and to trace the effects of those cosmological causes which were conjectured to have been employed by the Author of Nature to bring this planet out of a nascent and chaotic state into its present habitable condition.

Thus the philosopher Hooke, the contemporary, and, in some respects, rival of Newton, who entertained ideas of the nature and instructiveness of fossil organic remains far beyond his age, yet with a mind biassed by the idea of the Mosaic universal deluge, writes in 1688, "During the great catastrophe there might have been a changing of that part which was before dry land into sea by sinking; and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean in the interval between the creation and the deluge."

Woodward, Professor of Medicine, the founder of the Geological Museum of the University of Cambridge, and the collector of the most complete series of fossil organic remains of his time, mainly employed the numerous and instructive facts at his command to support a cosmological hypothesis, according to which "the whole terrestrial globe was taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid."

After Woodward, succeeded Burnet, with his "Sacred Theory of the Earth" (1690), in comparison with which, as Lyell truly remarks, "Even Milton had scarcely ventured in his poem to indulge his imagination so freely in painting scenes of the Creation and Deluge, Paradise and Chaos."

A remarkable comet appeared in 1680, and gave rise to many speculations on the nature and powers of those erratic celestial bodies, the boldest and most systematic of which were pressed into the service of geology, and made by Whiston the dynamical basis of his "New Theory of the Earth." This, like the preceding cosmogonies, retarded the progress of truth, by diverting men from the investigation of the structure and the fossils of the earth's crust, and by inducing them to waste their time in speculations on the power of comets to drag the waters of the ocean over the land, or condense the vapours of their tails into an overwhelming deluge.

To come nearer to the time of Hunter, we find that Buffon had also his "Theory of the Earth;" but as he did not profess, with Burnet and Whiston, to show that the explanation of geological phenomena and fossil remains, according to the Mosaic cosmogony, was "perfectly agreeable to reason and philosophy," the great naturalist received an official letter from the Sorbonne, inviting him to send in an explanation of his "reprehensible opinions;" the result of which was a declaration, in the next published volume, by Buffon, "that I abandon everything in my book respecting the formation of the earth, and, generally, all which may be contrary to the narration of Moses[1]." And yet, as one of our best living geologists has remarked, the principle which Buffon was called upon to renounce was simply this: that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will, in time, destroy all the continents, hills, and valleys, and reproduce others.

Werner, like Buffon, attributed all the geological phenomena of the earth to the operation of the waters. The great German mineralogist, who flourished contemporaneously with Hunter, appears to have regarded geology as little other than a subordinate department of mineralogy. His errors and failings chiefly arose from his mistaking the right aim of his labours, and committing himself, like his predecessors, to a general cosmological theory, that of 'universal formations,' which he supposed had been "each in succession simultaneously precipitated over the whole earth from a common menstruum, or chaotic fluid."

Werner's unrivalled quality was a tact in detecting the nature and composition of minerals, and their natural position in particular rocks. He successfully taught their external characters; and he was the first to direct attention to the constant relations of superposition of certain mineral beds. To the late venerable Professor Jameson, of Edinburgh, a pupil of Werner, this country is mainly indebted for the application of all that was sound in Werner's system to the advancement of geological science.

I have selected the well-known names of the eminent and highly gifted men who have committed themselves to 'Theories of the Earth,' in justice to the aim I have in view,—the exemplification of the truly philosophical character of Hunter's mind, of its peculiar adaptation to the discovery of pure truth, as exemplified in a field of his intellectual

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[1] [Neither Buffon nor Galileo cared to be 'Martyrs of Science.' There is something, perhaps, in the nature of abstract truth, that is less akin to our mixed and excitable nature than religious and political beliefs: some qualities in pure science that fail to engender so warm a devotion, because they come not so directly home to our business and bosoms, as the doctrines of State or Church, affecting more immediately our own special welfare here and hereafter. Man is not, therefore, so moved to lay down a life in the cause of cold abstract scientific truth, in the pursuit and acquisition of which he too often stands alone, as for a heart-cherished belief, in which many of his contemporaries eagerly sympathise with him, and are ready to encourage, applaud, and cherish with veneration the memory of suffering and sacrifice endured for the sake of common tenets.]

labours in which he has been, hitherto, almost unknown, but in the course of which he clearly recognized the great principle, that geological investigations "had nothing to do with the original formation of the earth, but had only a connexion with the changes on its surface."

There was but one cognate contemporary mind, so far as I can discover, who, like Hunter, fully appreciated the true aim of the geologist. I allude to Hutton, who, like Werner, was at work at the same time as Hunter.

In Hutton's 'Theory of the Earth,' published in the 'Edinburgh Philosophical Transactions' for 1788, it was for the first time declared that "Geology was in no way concerned about questions as to the origins of things."

"The ruins of an older world," writes Hutton, "are visible in the present structure of our planet; and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted."

Evidence of all these operations, productive of geological change, have since been abundantly made matter of observation. The characteristic feature of Hutton's mind was its freedom from any bias towards hypothetical violent causes; its exclusion of all causes not supposed to belong to the present order of nature; and the aim of his theory was to explain the former changes of the earth's crust by reference exclusively to natural agents.

In precisely the same spirit Hunter writes, "Our mode of reasoning on this subject may be termed retrograde; it is by supposing, from the state of the earth now, what must have taken place formerly." Now, mark the importance of basing geology on a knowledge of the state of the earth, as it is now: see the stimulus it gives to intellectual activity in the right direction; consider the nature and extent of observation in order to acquire that knowledge!

Most rapid, most unexpected, and at the same time most sure, has been the progress made in geology since men, in place of inventing causes and conditions unlike the present, have submitted themselves to search after the nature of those that now are in operation, and of whatever in the present state or inhabitants of the earth may be related to, or affected by, such operations.

The extent of this precise and enduring knowledge of the changes of the earth and the succession of its inhabitants, has been in the ratio of the investigations conducted on the philosophical principles of Hutton and Hunter, which are, indeed, those of the Inductive Philosophy of Bacon. Whether Hunter had perused the 'Theory of the Earth' in the 'Edinburgh Philosophical Transactions' of 1788, before he penned the passages copied out fair in 1792, must remain matter of opinion: in that MS. memoir, he quotes certain authors which he had consulted; and I incline, from every evidence of Hunter's habits of labour and thought in the pursuit of truth, to believe the remarkable essay, now under comparison, to have been, in regard to this fundamental principle of the true aim of geological research, strictly original.

At all events this is certain, that the success of geology and palæontology dates from the period when their cultivators abandoned any attempt to explain "the original formation of the earth itself," and restricted themselves in their reasonings on "the changes that have taken place on its surface," and to deductions from the present state of the earth, as to the nature of those changes that had formerly there taken place. The great difference between Hutton and Hunter is in the degree of importance they respectively assign to the evidence of fossil organic remains in the advancement of geological knowledge.

Sir Charles Lyell, than whom no modern geologist can entertain a higher appreciation of Hutton, states that, although "Hutton's knowledge of mineralogy and chemistry was considerable, he possessed but little information concerning organic remains; they merely served him as they did Werner, to characterize certain strata, and to prove their marine origin." The theory of former revolutions in organic life was not yet fully recognized. Hunter rises far above his contemporaries, when he states that "we should be unable to consider the causes of the operations affecting the surface of the earth if we had not the preserved parts of sea-animals. . . . . Just as we would trace the remains of former actions in any country, by the monuments left; judging of the past from the present."

The truth and beauty of this illustration of the use of fossils, has been appreciated more and more as the value of the evidences from organic remains has increased. Most probably (in my own mind, indeed, I have no doubt) the *simile* was original with Hunter. But it is so natural an idea—so likely to occur to any one appreciating, like him, the value of fossil remains, and their application to elucidate the history of the strata in which they are imbedded—that one cannot be surprised at its having occurred to others.

Thus Hook, in 1668, writes:—"However trivial a thing a rotten shell may appear to some, yet these monuments of nature are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design ..... and though it must be granted that it is very difficult to read such records of nature, and to raise a chronology out of them, and to state the intervals of the time wherein such or such catastrophes and mutations have happened, yet it is not impossible."

The same figure or simile occurs a hundred years later in Bergmann's 'Meditationes de systemate Fossilium naturali,' 8vo, Oxon, 1788, in which that great chemist, for his time, writes, "Horum contemplatio multiplicem habet usum. Sunt instar nummorum memorabilium quæ de præteritis globi nostri fatis testantur, ubi omnia silent monumenta historica."

Hunter proceeds:—"But it is to be supposed that any changes that may take place are superficial, respecting the size of the globe itself; for we have no reason to suppose that the materials necessary to work a change are deep, such as water, and whatever it can take into solution, as also airs; for, without these two states of matter, no combination of matter can take place.

"These changes are, forming solid matter into fluid, and from fluid into solid again; and it is in this last process that the recent vegetable and animal parts are, as it were, arrested or caught ..... Such substances so caught, are either preserved themselves; their impressions, which must be called a mould; or their substitute, which is a cast: such are termed Extraneous Fossils, ... many of which retain some of their form after many thousand centuries.'—P. iii.

We have already had to notice Hunter's appreciation of the true end of geology and palæontology, viz. to explain the past by what we know of the present, and not to invent causes now unknown, by speculations on cosmogony. How far such were from his habit of thought is shown by the following:—"Any changes that may take place are superficial, respecting the size of the globe itself; for we have no reason to suppose that the material causes of change, such as water, are deep."

We have here the indication of the comparatively small part of the earth that can be profitably or, indeed, possibly studied according to the true inductive method. The greatest depths of mines, the lowest soundings yet taken of the sea, the deepest insight which any upheaval or fracture of the earth's crust has hitherto permitted human eye to penetrate, or human mind to frame a deduction as to the structure of the earth, are extremely small in comparison with the semidiameter or radius of the globe. Accordingly the best modern geologists define their science as that which treats of the structure and changes of the 'crust' or 'surface' of the earth.

Thus the proper aim of geological investigation, the right way of investigating, and the true extent of the field of investigation, are, at the outset, recognized and defined by Hunter.

"Finding," he remarks, "upon land more parts of marine than terrestrial animals preserved, and at considerable depth, it naturally leads to the idea of sea-animals at least having undergone this process at the bottom of the sea; and if so, then as that [stratum] in which they are found is now land, and as we find parts of land-animals and vegetables preserved nearly in the same manner, it leads us into a more extensive investigation of the permanency of the situation of the waters; and in this inquiry we shall find that wherever an extraneous fossil is enclosed or imbedded, the surrounding native matrix was accumulated, disposed, or formed into that mass at the same time."—P. iv.

Here Hunter enunciates another important principle, the coevality of the fossils with the mineral strata in which they are found. This principle has since been abundantly established; the use of fossil organic remains, illustrated by Hunter's figure of human monuments and memorials, depends upon the demonstration of this proposition as a general rule. I do not find it so definitely laid down in geological writers prior to Hunter; although it was evidently appreciated in a certain degree, and with reference to particular strata, by some of Hunter's predecessors.

The exceptions to the rule arise from the formation of one stratum out of the ruins of a preceding fossiliferous stratum, when the fossils of that older stratum become, together with their matrix, a part of the newer one, with which, however, those fossils are far from being coeval in respect of the period when they actually became fossil. Petrified bones of Plesiosaurus, *e. g.*, have been transmitted to me, together with unpetrified bones of the beaver, from the comparatively recent 'till' of Cambridgeshire, the plesiosaurian remains having been washed out of the subjacent gault, when the sea finally retired from the uprising land. Such 'derivative' fossils were nevertheless actually inclosed or imbedded in the newer tertiary matrix when it "was disposed or formed into the mass," now called 'till.' The exceptions of such derivative fossils are, however, comparatively rare, and do not affect the conclusions, as to the relative age of a stratum, afforded by its obviously and much more abundant proper organic remains.

"It might be supposed that the fossils of sea-animals would be found in every known substance; because it is natural to suppose, as most substances have been formed at the bottom of the sea, that every kind would be formed there, but they are not; for no such fossils have yet been found in granite. Probably no cause can be assigned for this, although several opinions have been formed, such as granite being the original matter prior to vegetable or animal; which may be probable, although we have no reason to suppose that the formation of granite is different from all others."—P. iv.

One of the latest acquisitions of knowledge—subversive of a generally entertained idea in geology—bears upon the relative antiquity or priority of the superficial masses of granite, porphyry, basaltic, and other crystalline non-fossiliferous rocks, which, agreeably with that long prevailing notion, were called 'primary formations.'

Hunter alludes to the opinion as current in his time, viz. that "granite was the original matter prior to vegetable or animal;" but saw "no reason for supposing that the formation of granite is different from any of the others."—P. vii. The subsequent progress of chemical science has proved that granite is a product of intense heat; and that, like other crystalline rocks, it differs, in the cause of its formation, from stratified fossiliferous rocks. But satisfactory proof, since Hunter's time, has been obtained that some granites are not different in their formation, in point of time, from strata that contain animal and vegetable remains, but that they have been poured out since the deposition of the fossiliferous beds which have been upraised, distorted, or metamorphosed by the heat of such more recently formed and intruded crystalline rocks.

I will here merely refer to the section in the twelfth chapter of the fourth edition of Lyell's 'Principles of Geology,' headed "No proofs that these crystalline rocks were produced more abundantly at remote periods;" and to the admirable memoir by the Duke of Argyll on the tertiary age of certain basaltic strata in the Isle of Mull. Only an accomplished modern geologist will be able fully to appreciate the mind of Hunter, who in the last century, in reference to the then and long-after prevalent belief that such crystalline rocks were 'primitive,' or prior to the fossiliferous, or to vegetable and animal life, saw "no reason to suppose such difference to exist."

Hunter acknowledged, indeed, that he had obtained remains of sea-animals from every kind of mineral, except the granitic or crystalline rocks. But fragments of the greywacke slate, containing marine organic remains, have recently been found entangled in the granite of the Hartz, by M. de Seckendorf.

"We find," Hunter proceeds to say, "the remains of sea-animals in every kind of substance excepting granite. We find wood, bones of sea-animals, bones of land-animals, in freestone, gravel, clay, marl, loam, and peat. These are found, and at considerable depth, retaining most of their original composition; and we find wood, bones of land-animals, as also shells of sea-animals, even in the same bed, encrusted; each of which I shall consider.

"The vegetable and land-animal substance show that the sea has overflowed the land, and that it has afterwards left it, so as a second time to be land again; for it is on what is now land that all those fossils are found which must have been formerly covered with water; but previous to that it must have been land, which last is not absolutely necessary where only sea-productions are found."—P. v.

"They show the accretion, crystallization, precipitation, and subsiding of solid matter, or of all the different earths, both common and metallic, in all their different ways, which must have been either mixed or suspended in solution in the water prior to those formations we now find; they show the vast time the sea must have been in some places, to give us such depths of new accreted matter.

"Perhaps the depth in the earth of extraneous fossils might give us the quantity of depth of earth of native fossils, formed at any one time of the residence of the sea in the same place; . . . also, as the fossils now found in countries whose climate does not correspond with the climates now inhabited by the recent (which implies that the fossils can be matched by the recent), we are led to suppose that there has been an alteration in the ecliptic; and they also give us a hint what vegetables and animals are probably lost, or are not now found. The first of these, viz. the fossil not being readily matched, when fully settled, will in some degree explain the second.

"Not only the formation, or rather the mode of preservation, of wood and animal [fossils] is shown by their intermixture with the native, but the formation of native fossils is also shown by the vast variety of parts of sea-animals being found encased in them, and of all kinds of earths, viz. calcareous earth, flint, crystals, clay, sand, metals (as we often find iron and the pyrites joined with the extraneous fossil), and in all states of those earths, viz. some in powder, as chalk; wet powder, as clay; others crystallized, as flint, sand; calcareous earth, as marble, spar, &c.: but I have observed that we do not find extraneous fossils in granite, and yet we have no reason for supposing that the formation of granite is different from any of the others.

"The great depth and quantity of those extraneous fossils show that the sea must have been a considerable time there; however, the history of countries has shown this, without having recourse to collateral circumstances to prove it; for no extraneous fossils now found are within the period of history, not even those bones of land-animals found in peat, sand, gravel, clay, or those encrusted, which are most probably the most recent of all.

"The change in the ecliptic would appear by the fossils and recent of the same species having changed countries respecting warmth; for the fossils of this and other cold countries are the most recent in the warm; yet this is not universally the case, for I believe that bones of the elephant are found in all climates.

"It is very common to find in this country, as also in North America*, bones of elephants which are known by their teeth. It is the same with the sea-horse, as also the amphibia, as the turtle, with many shells of warm climates, &c.; a thing that most probably would not have happened if a change in the situation of this globe respecting the sun had not taken place."—P. vi.

This extract brings before us Hunter's views on another great geological principle,—the alternations of sea and land in the same place. First, let me beg attention to the perspicuity with which Hunter interpreted his evidences of the differences, in regard to the time during which such alternations had taken place; to his deductions as to the rapidity of the submersion of a tract of dry land, from the perishable nature of the fossils, as for instance, leaves, &c., found in such strata; and next as to the "vast time the sea must have been in some places" in order to allow of the depth of the new precipitated matter.

Hunter's deductions, that the sea must at some period have overflowed the now dry land, and that there had been alternations of land and sea, though doubtless original with him, and strictly in accordance with his premises, were not new: they are, in the main, the same as those which the excellent comparative anatomist Steno arrived at in 1669, from the study of petrifactions in certain strata in Italy. Steno, who had dissected a shark, and had recognized the identity of form and structure between the teeth of that fish and the fossil teeth, advocated the true view as to the nature and origin of organic fossils, which Leonardo da Vinci and Fracastoro had, nearly a century before, maintained; but which, under a mistaken and baneful impression as to the tendency of natural truth, and a dread of it, was in Steno's day rejected. Steno, in his remárkable work entitled "De Solido intra Solidum naturaliter contento," 1669, declares that he had obtained proof that Tuscany must successively have acquired six distinct configurations; having been twice covered by water, twice laid dry with a level, and twice with an irregular and uneven surface.

* The large tusks found in America do not belong to the animal whose teeth we find. I have a grinder of an elephant sent me from the same place.

So also Hunter writes: "It would appear that the sea has more than once made its incursions in the same place."

The proofs of such repeated uprisings and submersions of parts of the earth are now abundant and unequivocal.

There is no geologist, no observer with a mind capable of appreciating and interpreting the evidences of the dynamics that have affected the earth's crust, but admits that the entire surface of the earth has been beneath the sea, but not necessarily at one and the same time; that the alternations of land and sea have in many places occurred more than once; and that "vast periods of time" have elapsed in the course of these changes and operations.

With regard to the alterations of climate which Hunter deduced from the supposed identification of some of his fossils with those of recent animals, he was induced to refer the circumstance to "a change in the situation of this globe respecting the sun," in other words, to a "change in the ecliptic." Here he departs from his principle of explaining the past phenomena by present causes. Newton long since declared, in reference to a similar supposition borrowed by Burnet from an Italian author, "Allessandro degli Allessandri," in the beginning of the eighteenth century, that "there was every presumption in astronomy against any former change in the inclination of the earth's axis;" and Laplace has since strengthened the arguments of Newton, against the probability of any former revolution of this kind.

It may be a question, however, whether the mental stock now to be dealt with by the geologist does not yield a truer appreciation of the duration of time in which the movements of the stellar and solar systems have gone on, than could be afforded by the observations and calculations of the astronomer in the times of Newton and Laplace: whether the inadequacy of the analogy, based by Cuvier on the knowledge of the characters of a species during a period of 3000 years, of such seeming fixity of specific characters, to the effects of influences on generations succeeding each other during 300,000 years, may not be applicable to the case of Newton, considering the results of his observations and calculations under a preoccupation of the mind by the theological age of the world.

Hunter's recourse to 'a change in the ecliptic,' as well as to "some attractive external principle producing a great and permanent tide," such as Whiston's comet, *e. g.*, was, however, the consequence of a misconception or misinterpretation of the phenomena which those hypothetical causes were invoked to explain.

Hunter believed, for example, that the elephants' remains found in northern and temperate latitudes belonged to the same species, or at most to a variety of the same species of elephant, as that which now lives in tropical regions. Its specific distinction from the existing tropical elephants was then as little understood as the specific distinction of the African from the Asiatic elephants.

The moment that zoology and comparative anatomy had made such progress as to discern constant differences interpreted as specific distinctions, and to apply the same principle to the differentiation of the fossil elephant of northern regions from either of the existing tropical kinds, the necessity for calling in a cataclysm, either through a hypothetical shift in the ecliptic, or the attraction of the ocean upon the continents by a comet, no longer existed.

Yet Baron Cuvier, to whom we are indebted for the first scientific demonstration of the distinctive characters of the *Elephas primigenius*, was as little able to release his mind from the belief in the identity of the habits and food of the extinct elephant with those of the recent, as Hunter was, who nevertheless had not the same ground for conceiving a possible difference in its mode of life. Yet nothing is more obvious in zoology than that different species of the same genus are adapted by their very specific distinctions to different climates, have different habits, and subsist on different kinds of food.

Species of the genus *Sus*, e. g., exist in a state of nature in the forests of the tropics and of cold temperate latitudes. Who can forget that fine painting by Joseph Wolf, of the northern wild boar uprooting its scanty winter food in a furrow of snow? Wild boars are hunted in Scandinavia and in Bengal. Suppose the northern species to have become extinct, and the hog, in a wild state, to be known only as a denizen of the tropics: its remains, found in the cold latitudes in which it had formerly lived, would have suggested the same ideas, in reference to the necessity of a tropical climate, the same consequent appeal to a violent departure from the ordinary course of nature, as were entertained and mooted by Hunter in the case of the fossil elephant.

With regard to the influence of locality, and of the proportions and disposition of sea and land in affecting climate, I beg to refer to the 6th and 7th chapters of Lyell's 'Principles of Geology,' "On the dependence of the mean temperature on the relative position of land and sea," and "The conditions necessary for the production of heat;" and to the chapter on the "Siberian Mammoth," in my 'History of British Fossil Mammalia,' for the proofs that that species of elephant, together with the similarly warmly-clad rhinoceros, were originally Siberian, and adapted for a temperate if not a cold climate. In the next extract will be given Hunter's matured and final views on the supreme question of the extinction of species.

"There are very few fossils that can be matched with the recent, or [else] that the recent are not known now to exist: yet though very few fossils correspond with the recent, though very similar [to them], yet they may not be of different species, but varieties; for there is no more reason [meaning there is as much reason] for an animal in the sea varying from its original, from a difference in soil [sea-bottom] and other circumstances, than [as] there is for those upon land, which we see they do; but if they are really different species, then we must suppose the old are lost; therefore a new creation must have taken place. But that many are actually lost is, I think, plainly shown, by the remains of land-animals that are now not known. Yet how they became extinct is not easily accounted for."—P. vii.

Hunter puts the entire question hypothetically: he nowhere commits himself to a positive assertion. He knew that some fossils were "not matchable with the recent," but draws no hasty conclusion from this fact. Such recent analogues might exist, but be not yet discovered. The fact of extinction seems, indeed, to be "plainly shown by the remains of land-animals that are now not known:" and, "if they are really different species a new creation must have taken place."

But Hunter refrains from drawing, even from the same premiss, that extreme conclusion; for, where the fossils do not correspond with any known recent forms, and are only similar to such, "yet they may not be of different species, but varieties." He puts it all hypothetically: and this caution and reticence are eminently consistent with every evidence we now possess of his intellectual idiosyncrasy[1].

Hunter, doubtless, called to mind the vast tracts in the interior of Africa and Australia which were unexplored in his day, and where probably such analogues of otherwise unmatchable fossils might still exist. On the degree of that probability I may afterwards have something to say. With the possibility, so much greater in Hunter's time than the assiduous explorations and extensive collections of Naturalists have since made it, it was incompatible with his caution and pure love of truth to commit himself to an absolute conclusion. But if even

[1] [The fact of extinction being now commonly admitted, the editor of the College edition of the present manuscript, of course affirms of Hunter, "He had, however, perceived the true nature of these fossils as relics of animals no longer living on the surface of the earth, as having belonged to a former creation, so that, in his own phrase, they could not be 'matched with the recent' [an absolute assertion nowhere to be found in the MS.]; he felt that the extinction of such races, &c., can only be explained by revolutions in the surface of the globe during periods of immense, but indefinite and uncertain duration. He may therefore be regarded as having laid the foundation of that interesting branch of science for which his modern successors have devised the name of Palæontology."—Preface. p. 3.]

Hunter had been able to exclude from his careful outlook all possible causes of deception, and had pronounced absolutely on the extinction of species, the honest and competent commentator would feel bound to quote from the eloquent 'Epoques de la Nature,' Buffon's proposition, "Qu'il y a eu des espèces perdues, c'est-à-dire, des animaux qui ont autrefois existé, et qui n'existent plus[1]."

But we may safely assert that neither assertions would have established or made current the great idea. Palæontology must have demanded more determinate, fixed, and extensive foundations.

Baron Cuvier, by his comparisons of the fossil bones and teeth of the land-animals dug out of the gypsum quarries at Montmartre, first and finally set at rest all doubts as to entire species and races of animals having perished. The foundations of Palæontology cannot be said to have been laid before his time.

Every science more or less depends upon another, and geology has most of these interdependencies. A rich zoology in the number of observed animals and their geographical relations,—a precise zoology in regard to definitions of specific identities and differences,—were an essential preliminary to the determination of the specific relations of organic remains.

Now this truly scientific zoology was but dawning in the days of Hunter: it is to the great French Natural History School, which succeeded Buffon and Linnæus, that science is indebted for the state of Natural History which made a scientific Palæontology possible. Take the distinction of the African and Indian elephants, *e. g.*, and the difference in the dentition of both, from that of the fossil northern elephant, as exemplifications of the grounds on which specific differences have been founded. In like manner the determination of the distinct species of the living and extinct rhinoceroses on the Cuvierian basis was indispensable for any correct inference from the fossil remains of that genus.

The fallacy of the reasoning from the fossils of the Elephant and Rhinoceros, as to changes of climate, and the consequent invocation of a change in the ecliptic, arose entirely from the defective state of zoology and of comparative osteology and odontology at the time when Hunter wrote. He accomplished vast things in his favourite science; he could not do all!

Far from offering any explanations, by revolutions in the surface of the globe, &c., Hunter, after hypothetically suggesting the possibility of some species having become extinct, plainly states that

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[1] [Histoire Naturelle, 4to. tom. v. p. 27 (Supplément), 1754.]

"How they became extinct is not easily accounted for; for although we must suppose that the species of deer [*Megaceros*] to which belonged the bones and horns now found in the island of Great Britain, more particularly in Scotland, and still more in Ireland, is lost, yet we have reason to believe they were coeval with the elephant; for I have the lower jaw and tooth of an elephant that were dug up at Ougle [Oundle], in Northamptonshire, twelve feet below the surface, in a strong blue clay; and with it, one of the horns of the large deer."—P. viii.

This opinion of the antiquity of the *Megaceros* has been confirmed by later observations: in Ireland its remains occur in the shell-marl underlying the turbary[1].

Hunter proceeds to express his thoughts on the nature of fossil organic remains, as follows:—"No definition can be given that will suit every fossil, except simply that which strikes the eye, which in a general way is pretty correct. For as extraneous fossils have been and can be matched by such substances in a recent state, and probably the animals most [frequently], they may in a general way be distinguished, and this arises from the part in a fossil state having been more or less deprived of the parts belonging to the recent, which is the animal part; and which is what principally gives colour to them: thus fossil shells have none of those bright colours found in the recent; yet some shells retain something of their original colour, though the animal part is dissolved into a kind of mucus, which would make us conceive that both the animal and earthy parts were so disposed as to reflect nearly the same colours, but the animal part is by much the brightest: for it is not simply the state in which the substance is that constitutes a fossil; but it is the state, with the mode in which it was brought to that state, that commonly constitutes a fossil; for many things might be called an 'extraneous fossil' if considered abstractedly from the manner of their being brought to that state; [and, so considered,] every churchyard would produce fossils."—P. xxiv.

"To establish the principles of fossils, I shall set it down first as a principle, that no animal substance can of itself constitute, or be turned into, a fossil; it can only be changed for a fossil*." Note the acute distinction drawn between 'turned into' and 'changed for.' Hunter next notices the change of animal matter into 'adipocire,' and remarks,—"How far critics will consider such to be a fossil, I will not say. . . . . We find vegetables preserved in the earth retaining their original properties;

* What I mean by animal substance, is everything that constitutes animal matter which is not earth.

[1] [History of British Fossil Mammals, 8vo. 1846, p. 464.]

but which I believe are seldom called 'fossils.' But we have many extraneous fossils imitating all the appearance of wood, many of which had wood for their base; we have also the impressions of leaves, &c.

"But pure animal substance without any mixture of earth, stands still a less chance of becoming the basis of a fossil; for they are more dissolvable in themselves, or perishable, than most vegetables; even less chance of having a mould formed upon them; therefore we have fewer of them. However, some animal substances are solid enough to preserve them a sufficient time to have a mould formed upon them, viz. the scales of the turtle, fish, and some insects, &c.: even horns might be preserved a sufficient time. However, of these two last there are very few in number that can have the opportunity of having a mould made upon them; but as we have no casts of the beaks of the cuttle-fish in a fossil state, we may suppose that even this substance is not sufficiently preservable[1].

"The difference of the impressions of fish in marl schistus, and in the bituminous schistus, appears remarkable. In the marl schisti which contain impressions, such as those of Verona[2] and Pappenheim, it is the skeleton of the fish which has made the principal impression, whilst the skin appears like a film (which certainly helps to make manifest the figure best), through which the impression of the bones are distinctly seen, as if the soft parts of the animal had decayed before the mould was made. On the contrary, in the bituminous schist, such as those of Eisleben[3], the figure of the fish appears complete, as if the impression was made before any part of the animal had suffered any alteration by putrefaction; it is probable that this difference has been occasioned by the property of bitumen in retarding or preventing putrefaction."—P. xxvi.

The principal, perhaps sole, cause of the difference here noted by Hunter between the Ichthyolites of the tertiary schists of Verona and

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[1] [Hunter, when he wrote this passage, had either not received, or not given his usual attention to, the beautiful fossil from the oolitic slate of Solenhofen, No. 2, 'Catalogue of Invertebrate Fossils,' in which, after determining its nature under the name of *Leptoteuthis gracilis*, I described "the mandibles as moderately long, slender, slightly arched, trenchant, pointed, and wholly horny, as in other Dibranchiate cephalopods."—P. 3. 4to, 1856.]

[2] [Catalogue of Fossil Reptiles and Fishes, No. 641, *Smerdis micracanthus*, "from Mount Visiena Nova, near Verona."]

[3] [Ib. No. 613, "Impression of a Fish: the head quite crushed, the tail also crushed: many of the scales are bronzed: from Eisleben, near Mansfeldt, Upper Saxony." Orig. Hunterian Catalogue. In the 'Catalogue of Fossil Reptiles and Fishes,' 4to, 1854, p. 153.]

Monte Bolca, and of the Permian schists of Eisleben, is the different structure and composition of the scales of the extinct fishes of those two remote geological periods. In the earlier (Permian) period the fishes were 'ganoid,' or had bony and enamelled scales which became petrified: in the later tertiary period the fishes were 'cycloid' or 'ctenoid,' *i. e.* had flexible and soluble scales like those of most osseous fishes of the present period. With the better dermal ossification of the older fishes was usually associated a less complete ossification of the endo-skeleton, and the reverse in the later fishes; all which circumstances combine to make the evidences of 'secondary' fishes to be chiefly scales, and those of 'tertiary' fishes chiefly skeletons.

Hunter divides fossils into three kinds: first, fossils proper, having as a basis the earth of bones and shells, retaining their shape, though not always their texture; secondly, 'casts;' and thirdly, 'moulds.' "What are called 'vegetable fossils' are no more than either a change of matter, or a cast; and in leaves or soft vegetables there is nothing but the mould, the two sides of which are in contact, as if pressed together after the impression had been made and the vegetable destroyed."—P. xxxi.

"Another species of fossil is a gradual decomposition, and a new deposit; where the whole parts originally composing the bone have been removed, and an earth of some kind deposited in its place, keeping up all the same structure and arrangements as in the original bone. That this is the case must be evident, as there is not a single grain of calcareous substance in the whole composition."—P. xxxiii.

"We find the cavity formed by the two valves [of a bivalve shell] often filled with different earth; frequently very beautiful crystallization in it; the same in the univalves, and, which is very common in the Nautilus and Cornu Ammonis, their cavities being not easily filled with gross matter. Some have, in the place of the shell, constantly a cast of a peculiar crystallization forming calcareous spar, such as the Echinus, the Encrinus, and probably all of the star-fish kind, which would seem to have been decomposed, and a new mode of crystallization has taken place. Their structure in the fossil state is certainly not similar to the natural. It would appear that the original had hardly sufficient calcareous matter to form such crystallization, though probably not new matter. Such are often found in chalk, and filled with the same, or are imbedded, as also filled with a siliceous matter from a pale to a black flint."—P. xxxiv.

"The sea has afforded the truest fossils, and the greatest number: . . . . Rivers," Hunter proceeds to say, "carry into the sea various earthy matters either mechanically mixed or in solution, which matters convert themselves into extraneous fossils by forming either a mould or cast, or both, of the organic remains either at the bottom of the sea, or which are carried into it. Thus the sea has both the fossilizing materials and the bodies to be fossilized. The sea gives life, and of course contains a much greater number of animals than the same surface of the land does. . . . . . Such are constantly dying, and such parts of them as are not perishable, such as the earth of bones and shells, will, by losing the animal part, by time, become what we may call a 'Fossil:' and others, from being in water impregnated with such materials as are capable of imbedding their substance, or filling their cavities with such matter, will also be considered as 'fossil'."—P. xxxvi.

"We may observe that the amphibia, and such as inhabit both the sea and land, as all of the Phoca-tribe, white bear, &c., likewise sea-fowl, partake of the before-mentioned mode of fossilization, by dying in the sea; for wherever there has been a shore, there we shall find the amphibia; as also many of the fowl-tribe, called sea-fowl, which feed in the water, which may die in the sea near the shore, or be brought down in the rivers, will be carried into the sea, and be fossilized according to the fore-mentioned method, and will be found along with the sea productions. But they will also partake of the second situation, as in large valleys leading to the sea, which were formerly arms of the sea or inlets, which are to be considered as having been moving shores, as the sea gradually leaves the land, leaving materials it had robbed higher land of, raising the bottom, or forming a new surface, lessening the depth of water at these places, which renders it slower and slower in its motion, as before described, at last becoming a river. Such new land will bury in it such productions, whether of sea or land, but most of those common to both, as shall either die in it, or being brought into it, constituting chiefly such animals that inhabit both land and water, as also amphibia, with land-animals that came there, or vegetables that were brought there, making a heterogeneous mixture. And I believe it may be observed in general, that the fossil bones of land-animals or birds are commonly found in such deposited materials, as gravel, sand, clay, &c."—P. xxxvii.

"But the preservation of vegetables and land-animals is most probably not confined to such situations alone. A change in the situation of the sea most probably has been a cause in the production of such fossils, which constitutes a third situation of the production of fossils. Therefore, to preserve vegetables, bones of land-animals, and many birds, one of two circumstances must have taken place: first, a change of the situation of the sea upon the land where such productions are. But in [regard to] what may be called 'land-birds,' there will be a few of them [found fossil]; for hardly any change in the land or sea can take place but what they can follow,—the new rising land, as it were, growing out of the waters, and abandoning the old, which now becomes covered with the waters."—P. xxxviii.

"But we find wood in greater plenty fossilized, according to the first situation, and which was most probably in the depth of the sea, than the bones of land animals. We also find wood which has been affected by the sea at two different periods; first, when in the state of wood, [during which period] it has been eaten by the Pholas [*Pholadidæ*][1], and their canals have been filled with flint, &c.; and then the wood itself has been changed, I suppose, as above described. We also find wood eaten everywhere and in all directions by those worms [*Teredo antenauta*], which we find eating the bottoms of ships at this day, and their canals filled with spar, and the woody texture changed. I have also wood whose mucilaginous parts have been destroyed or decayed, and the interstices, or first canals, which may be considered as sap-vessels, are filled with calcareous earth, making it hard and heavy; and when steeped in the muriatic acid, the wood comes out to appearance entire, but could have been crumbled down to a powder. I have a piece of wood which has lost its mucilaginous part, and its two ends are, as it were, tipped with agate, as if half-changed."

"We find fossil wood not much different from wainscot; and what makes me call it fossil wood is, its ends, and some of their interstices, are filled with agate. . . We find agate representing wood in every respect excepting in the species of matter: we find it imbedded in stone, as Portland stone, &c.; and in such it has commonly undergone a complete change; and what is very curious, it shall be imbedded in a kind of hard freestone, and yet itself shall be agate, therefore has probably undergone a change before it was imbedded: and probably the mode of decomposition and new combination led to this difference between wood and agate; for as one particle of the vegetable is destroyed or removed, a particle of earth is deposited in its place, something similar to the double elective attraction, something similar to putting a piece of iron into a solution of blue vitriol; but the particles of earth deposited must be equal in size to the particles of vegetable removed, therefore much more in quantity than what there was of earth in the particles of vegetable; and one could almost conceive that it was simply an exchange, for the centre of such fossils are commonly much the hardest, while the outer parts appear hardly to be changed. This mode gives the appearance of the original structure of wood, giving the strata [of growth], as

[1] [Hunterian Specimens, Nos. 1013, 1014.]

also the knots. Even colour would appear to arise from this exactness of disposition, for the layers are often of different colours, probably similar to the original wood. If so, then colour arises more from the mode of arrangement than from the kind of matter[1]."—P. xxxix.

"In peat, one could conceive that the trees had only to fall, and afterwards to sink down into it; but I believe no such wood grows in peat, therefore they must have been brought there, and that only by water; or [they may have] grown there prior to the formation of peat. But the animals which could come there had only to die on the surface, and in time they would also sink deeper and deeper into it; and this I imagine might be the case with the beavers in this country, whose bones are found in the peat-mosses in Berkshire. Or, as peat is supposed to grow, we can conceive it rising higher and higher above such substance.

"Bones are also found in gravel, clay, marl, loam, &c.; and as we have found the sea-horse bones [*Hippopotamus*] in gravel, &c. in this country, I am inclined to think that such situations have been shores or arms of the sea, at last constituting mouths of rivers, where the animals have been accidentally swept away by floods, accidentally drowned, &c., where gravel, clay, &c. have subsided, as before described; for it gives more the idea of being a consequence of the sea leaving the land than an effect produced by a continuance of the sea in the part, according to our idea of the formation of the true fossil. But the difficulty is to apply this to the bones of some animals that do not now exist in the same countries where they are found; as also [to] the bones of animals that probably do not now exist in any country.

"This looks like a destruction of the whole species of such animals at the time [during] which [those] animals were probably confined to such countries; and which might also be the case with the beaver in this country; and it being a more universal animal, its species is preserved in other parts. The same observations apply to the sea-horse [*Hippopotamus*], as also to the elephant." . . . .

"Thus we have in many parts of this island the bones of unknown animals, such as a large species of deer [*Megaceros*], as also the core of the horns, and bones, of some very large animals of the bull-kind [*Bison priscus, Bos primigenius*].

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[1] [P. xl. I had determined and named a large proportion of the vegetable fossils of the original Hunterian collection, at the time when I resigned my offices in the College of Surgeons, and when the completion of the Fossil Catalogue was left to others. I know not why all notice of these instructive fossils, together with the MS. so frequently referring to them, should have been omitted in the third volume published towards the close of that year.]

"There are many more of such bones as are found in the peat in Ireland; many in Scotland, both in peat and other substances." . . . .

"I also bring into this class the animal whose teeth are sent us from America [*Mastodon giganteus*], as also from Siberia [*Elephas primigenius*], of an immense large size.

"It is reasonable to suppose that this animal does not now exist anywhere. And as the deer, whose bones we found in this country and in a similar way also, does not exist, we may suppose that the destruction of them both was similar; and as the elephants, sea-horses, beavers, &c., do not exist in the countries where these bones are found, we may suppose that in these countries they were subject to the same fate; but such being more universal animals, the species are preserved where such [destructive] cause did not take place."—P. xlvii.

With regard to the antiquity of the human race, Hunter quotes a letter which he had received from Sir James Hall, of Scotland, dated Rome, February 24th, 1785.

In this letter a hill is described that lies about three miles from Rome, in the road to Loretto. "It is about 300 or 400 yards beyond an old tower, called Torre del Quinto. A tomb, called Ovid's, is dug into it, and fifty or sixty yards nearer Rome is a gravel-pit, which is the spot in question. The hill terminates abruptly in a vertical crag, at the foot of which the road passes, leaving it on the left hand as one goes from Rome. This crag exhibits the internal structure of the mass, which consists of horizontal strata. The hill is about 100 feet high above the level of the plain along which it passes:—

"1st. The upper part, on which the vegetable earth rests, is a bed 60 or 80 feet thick, of a kind of tufa or soft volcanic stone, full of lumps of black pumice of the size of a fist, more or less.

"2nd. A stratum of rolled pebbles, of various kinds of stone, some calcareous, some flinty, and some pumice. In general they have undergone some action, which makes them crumble when taken out; in some places they are bound by a calcareous cement, and in others little attached, and mixed with sand. This stratum is about 3 feet thick in one place, and tapers from right to left to the thickness of a few inches, on an extent of thirty or forty yards." . . . .

"We found the bones contained in this box in the first stratum of gravel between the two beds of tufa. We got up to this place by a bank formed by the crumbling of the hill above, and the matters thrown out of the gravel-pit on the right side of it. There is the greatest reason to suppose that the place where they were found had never been moved since the tufa came there; that is, that the bones and the stones of the stratum were placed there by the same cause, and previous to the formation of the upper bed of tufa [viz. that which is 60 or 80 feet thick].

"The place in which we found the bones extends 8 or 9 feet from right to left, and probably goes further to the left in that place, where the stratum of gravel passes along the roof of the gravel-pit; but there it was inaccessible. We did not dig anywhere above 3 feet into the bank, being afraid of bringing down the rock above by undermining it. It appears certain that the bones were brought there, along with the pebbles, loose, as bones, not in carcasses, for they lie scattered together without the least connexion; and their number is so great, compared to the space they occupy, that there would not have been room for so many bodies.

"Their nature is various, and indicates the presence of at least five or six distinct kinds of land-animals, and among the rest, two individuals of the human species.—J. Hall."

"This hill [Hunter proceeds to say] must have been formed before the Romans took possession of this place, and probably by the formation of the hill. The Tiber made its way in this direction, for it cuts the hill across. This is probably the only instance met with of human bones being in such a state[1]. But in future ages, when the present rivers may

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[1] [Flint-weapons, called 'celts,' unquestionably fashioned by human hands, have been discovered in stratified gravel, containing remains of the mammoth, in the valley of the Somme, near Abbeville and Amiens, at different periods, from the year 1847 (Boucher de Perthes, 'Antiquités Celtiques et Antediluviennes,' Paris, 1849) to the present time. These evidences of the human species have been extracted from the deposit in question, by Mr. Prestwich, 17 feet from the surface in undisturbed ground (Proceedings of the Royal Society, May 26, 1859), by Mr. Flower, at 20 feet from the surface in a compact mass of gravel ('*Times*, November 18th, 1859), by M. Gaudry ('L'Institut,' October 5th, 1859), and by M. G. Pouchet, all with their own hands, in the course of the year 1859. Besides the *Elephas primigenius*, remains of *Rhinoceros tichorhinus*, *Cervus somonensis*, *Ursus spelæus*, and of a large extinct bovine animal have been found in the same bed of gravel. Mr. Prestwich, after a careful study of the geological relations of this bed, refers it to the post-pliocene age, and to a period "anterior to the surface assuming its present outline, so far as some of its minor features are concerned."

Similar flint-weapons had been previously discovered by Mr. John Frere, F.R.S. ('Archæologia,' vol. xiii. "An Account of Flint-weapons discovered at Hoxne in Suffolk," 1800), in a bed of flint-gravel, 16 feet below the surface, probably of the same geological age as that in the valley of the Somme.

Flint-weapons have been discovered mixed indiscriminately with the bones of the extinct cave-bear and rhinoceros; one in particular was met with beneath a fine antler of a rein-deer and a bone of the cave-bear, imbedded in the superficial stalagmite, in the bone-cave at Brixham, during the careful exploration of that cave, conducted by a committee of the Geological Society of London, in 1859.

Dr. Falconer has communicated (Proceedings of the Geological Society, June 22, 1859) the results of his examination of ossiferous caves in Palermo, and, in respect take a new turn [through localities] in which are deposited human bones, many may be found; for, in sinking the caissons for Blackfriars Bridge, a human skull was found twelve feet under the bed of the river."—P. liv.

Hunter again returns to the subject of the evidences of geological action and of change of climate afforded by fossil remains, in the following passages. "As most of the extraneous fossils we find are the remains of sea-animals, it becomes the basis of our argument that the superficial native fossils were formed or accumulated at the bottom of the waters, and therefore we must suppose that the sea must have been in those situations where we now find the extraneous fossils, and there they must have been fossilized while the sea was upon them. This leads to the investigation of what might be called the progressive motion of the waters; but how far there is any systematical regularity in this shifting of the sea, time alone can discover; for there are little signs of it.

"We may observe that most countries have some of both vegetables and animals peculiar to themselves, although many vegetables and animals are common to every one; and this peculiarity is more confined to latitude than longitude; therefore if we were to reason entirely from the present vegetables and animals on this globe, we should suppose that the vegetables and animals found in a fossil state in any latitude

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to the 'Maccagnone Cave,' he draws the following inferences:—that it "was filled up to the roof within the human period, so that a thick layer of bone-splinters, teeth, land-shells, coprolites of *Hyæna*, and human objects, was agglutinated to the roof by the infiltration of water holding lime in solution; that subsequently, and within the human period, such a great amount of change took place in the physical configuration of the district as to have caused the cave to be washed out and emptied of its contents, excepting the floor breccia and the patches of material cemented to the roof, and since coated with additional stalagmite."—P. 136.

Sir Charles Lyell believes "the antiquity of the Abbeville and Amiens flint instruments to be great indeed if compared to the times of history or tradition..... It must have required a long period for the wearing down of the chalk which supplied the broken flints for the formation of so much gravel at various heights, sometimes 100 feet above the present level of the Somme, for the deposition of fine sediment, including entire shells, both terrestrial and aquatic, and also for the denudation which the entire mass of stratified drift has undergone, portions having been swept away, so that what remains of it often terminates abruptly in old river-cliffs, besides being covered by an unstratified drift. To explain these changes, I should infer considerable oscillations in the level of the land in that part of France—slow movements of upheaval and subsidence, deranging, but not wholly displacing, the course of ancient rivers. Lastly, the disappearance of the elephant, rhinoceros, and other genera of quadrupeds, now foreign to Europe, implies, in like manner, a vast lapse of ages, separating the era in which the fossil implements were framed and that of the invasion of Gaul by the Romans."—Address, on opening the Section of Geology, at the Meeting of the British Association at Aberdeen, Sept. 15th, 1859.]

would correspond with the recent vegetable and animal of the same latitude; but we find this not to be universally the case in every vegetable or animal, although it is so in some. It therefore leads to a supposition that not only had the sea shifted its position respecting the surface of the globe, but that the position of the poles respecting the sun had been altered, so as to have thrown different surfaces of the globe opposite the sun, which might be the cause of the waters shifting; and this supposition arises from the fossil parts of animals of one climate being found recent in that of another [*i. e.* animals found fossil in one climate are recent in another], instances of which we have many; and many recent animals of a peculiar climate are found in a fossil state universally, while many are not yet matched in any. I shall only take the elephant as an instance of the second: I suppose that this animal can only live in a warm climate. The preserved bones of elephants being almost universally found, is a proof of their having been either at one time, or at different periods, a very universal animal. . . . .

"History gives us no determined account of this change of the waters; but as the Sacred History mentions the whole surface of the earth having been deluged with water, the natural historians have laid hold of this, and have conceived that it would account for the whole. Forty days' water overflowing the dry land could not have brought such quantities of sea-productions on its surface; nor can we suppose thence, taking all possible circumstances into consideration, that it remained long on the whole surface of the earth; therefore there was no time for their being fossilized; they could only have been left, and exposed on the surface. But it would appear that the sea has more than once made its incursions on the same place; for the mixture of land- and sea-productions now found on the land is a proof of at least two changes having taken place."—P. x.

In appreciating the inadequacy of the Noachian deluge to account for the marine strata and fossils now forming dry land, Hunter had been preceded by many kindred minds, endowed with the divine faculty of discovering truth.

In 1517, Fracastoro, an Italian philosopher, in reference to the numerous marine animal remains brought to light in the excavations made during the repairs of the city of Verona, contended that those fossil shells had all belonged to living animals, which had formerly lived and multiplied where their exuviæ were found. He exposed the absurdity of having recourse to a certain 'materia pinguis' or plastic force, which it was said had power to fashion stones into organic forms; and with no less cogent arguments, he demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge.

That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. The close similarity, in the clear and philosophical views and words of Fracastoro, to those of Hunter (who we may safely believe had never read, or probably heard of the Italian author), are very striking. I need not trespass on your time by recounting the hundredfold additional and diversified testimony, which God, in his wisdom, has suffered to be made manifest, and to be irresistible in producing conviction according to the means of appreciating truth with which He has been pleased to endow the human understanding, in demonstrating the utter inadequacy of any of the brief and transient traditional deluges to account for observed geological and palæontological phenomena.

As the astronomer in teaching his science gives the results of the exercise of those faculties of observation, comparison, and calculation which have been given to him for the purpose of making known the Creative operations in infinite space, without enlisting any aid or element of science from the records of Creation in the sacred history of the Jews, so ought the naturalist or geologist equally to abstain from any foregone conclusion as to mode or time of operation which he might believe himself able to derive from divine teachings given for another end. He ought to confine himself to the deductions which rest on observation and experiment, and to teach those natural truths only which he has been privileged to establish by the exercise of the talents entrusted to him for the discovery of the Creative operations, or the power of God, in the immeasurable periods of the past.

Far from confining his notions of the nature of the aqueous force modifying the earth's crust, to a single transient cataclysmal operation, Hunter remarks, "The motion of the waters is what we may consider as the regular system of the world; the sea the greater part, the lakes and rivers the lesser; each formed out of, and forming the other. The lakes and rivers, though not the greatest, yet not inconsiderable, when we take in the valleys and low countries that lead directly into the sea, [these] having been formerly the seat of the sea, which, at a certain period of its retreat, exposed, first the higher grounds, then the great inlet; whilst in many places the surface of the earth, from its formation, retains the water, forming lakes of various sizes, becoming a temporary deposit for the water as it flows from the now land, as also a permanent deposit of whatever these waters may rob the land of; for I do conceive there was, in the retreat of the waters, a regular gradation; first, the whole being sea; next, many of what are now valleys forming the great arms or inlets; then, lakes; and afterwards dry ground; and that those lakes that now exist were much larger. For we may observe that the rivers that supply those lakes are carrying along whatever can be mixed with them, and with such rapidity as not to allow of a deposit till [they have] arrived at the lake; while, on the other hand, the water which runs out is clear, because it runs from the surface of the lake."—P. xi.

Hunter then proceeds to consider the mode of operation of water, by its wearing power when in motion, and by the deposit of matters carried along, and retained for a longer and shorter time in suspension; as illustrated by the deposits at the mouths of the Scheldt, the Rhine, and the Maese.

"This must be more remarkable with the Ganges, which runs through an extent of 1500 miles, and shall only descend 20 feet in 60 miles; the Nile; the Mississippi, which runs above 2000 miles, and opens by a vast number of rivers, with many of the other vast rivers in America, which become the great deposit of the materials of the river brought from the land above." Speculating upon the results of this aqueous action, he writes:—"The Red Sea will in time be only a flat valley, through which the rivers which empty themselves into it will run, terminating in the sea in one or more mouths, according to the surface at the bottom, which probably may form a country like Holland; and in all probability the Red Sea and the Mediterranean were one piece of water, which would have made Africa an island; and it is very probable the Mediterranean will be some day a lake, like the Caspian and the Black Sea."—P. xiv.

"The mechanical substances being of different kind respecting solidity, are accordingly carried to very different distances. Gravel goes but a little way; sand a little further; clay and chalk still further; and if we were to trace the mould on from an inland country towards the sea, in the course of a river, we might find the following appearances—gravel; gravel and sand; sand and clay, forming loam; or sand and chalk, forming marl; and at last wholly clay, which will be carried more or less some way into the sea."—P. xix.

"In these deposits of sand and mud are found the bones of large animals, such as elephants, rhinoceroses, buffaloes, &c.; and indeed these are found along the banks of almost all the rivers in Siberia, scattered here and there, sometimes in greater, sometimes in less numbers. The beds in which they are found are mixed with fish-bones, glossopetræ, wood loaded with ochre.

"Clay, from being a compressible substance, will be compressed more or less, becoming hard as stone, also forming select masses. It may even have a disposition to form itself into nodules; and probably some circumstance may lead to it, as having an extraneous body in it, as part of a vegetable, round which it seems to accrete, assisted in this operation by what may be in solution in the water, also forming what is called the Ludus Helmontia."—P. xxi.

"From this account it would appear that there is a kind of system going on; that the sea is the great reservoir of the materials of this globe, and the rivers, tides, currents, &c. of the sea, the active parts, without which the world would be at rest. When we consider the consequence of all these operations, we may be better able to form an opinion of the mode of new increase of matter in some places on the surface of this globe, in which will be vegetable and animal productions, which will give some idea of fossilization."—P. xvii.

Besides the indications of the general principles which Hunter had discovered for himself, or had accepted for his guidance, in the study and contemplation of the grand phenomena of the past creations and revolutions of the earth's surface, we find in the remarkable essay recovered from his posthumous manuscripts some instances of the results of the special application of those principles to particular geological phenomena.

Take those which must have most frequently presented themselves to his observation, as, *e. g.*, in the valley of the Thames, and note the broad interpretation that he gives of the facts so observed. "Probably," he writes, "the whole flat tract of the river Thames, between its lateral hills, was an arm of the sea; and as the German Ocean became shallower, it was gradually reduced to a river: and the composition of this tract of land, for an immense depth, would show it, viz. a gravel, a sand, and a clay, with fossil shells in the clay 200 or 300 feet deep, all deposited when it was an arm of the sea, and above which are found the bones of land-animals, where it has been shallow."—P. xv.

Hunter does not, indeed, specify the nature of the shells: they are, however, of a kind that could leave no doubt on his mind of their marine character. With his fossil specimen of *Strombus coronatus*, Dfr. (No. 561), he has placed the recent *Strombus accipitrinus* from the South American seas. He had also obtained *Rostellaria macroptera*, Lam. (No. 570), from the eocene tertiary at Hordwell, Hants; *Voluta nodosa*, Sby. (No. 747), from the London clay; *Mitra elongata*, Lam. (No. 781), from the eocene at Grignon, near Paris; the gigantic *Cerithium* (No. 783), from the same formation and locality; the *Crassatella tumida*, Dh. (No. 1095), from Nummulitic strata of the Swiss Alps; and the great *Nautilus imperialis* from Sheppey (No. 137), so like the pearly Nautilus from the nIdia seas:—all these shells, selected from a hundred other specimens in Hunter's cabinet, must have presented to their collector unmistakeable features of the marine origin of the strata containing them.

Subsequent researches, aided by the refined conchology of modern science, have established the truth of Hunter's conclusion.

All the shells of the London clay which forms the bottom of the tract through which the major part of the Thames flows, are of marine species, and most of them extinct. In the superficial gravel have been found fluviatile shells, most of them of recent species, with the remains of elephant, rhinoceros, hippopotamus, and other large terrestrial quadrupeds.

The following remarks show how closely Hunter had studied his fossil shells with a view to geological deductions.

"Parts of sea-animals as were capable of being preserved till fossilized, such as shells, must have often lain long at the bottom of the sea before the formation of the surrounding medium took place; this is plainly shown by the *Pholas* having eaten into them, which could not have been done but when [they were] lying at the bottom of the sea.

"Many fossil shells are covered with shells of another kind; but this may have taken place while the animal was alive in them; as we often see the same thing in recent shells. But we often find that the shell has become a mould, and afterwards the shell has been dissolved, and only the cast left, and on this cast we shall find the shells of worms, and the holes of the *Pholas*, so that the cast lay at the bottom of the sea after the shell has been separated from it or destroyed.

"Many shells are bruised, and have been afterwards filled with matter, which also shows that they have lain some time at the bottom of the sea, and that heavy bodies have been formed, and put or fallen into motion.

"Many have lain so long at the bottom of the sea as to have their cavities filled with matter, and afterwards to have the shell entirely destroyed, so that nothing but the cast remains, and upon this cast living shell-fish have fastened themselves, similar to their fixing upon any other stone in such situation; all of which could never have been done if the whole had not lain at the bottom of the sea for a considerable time.

"Many shells have lain at the bottom of the sea, where the water has been agitated so much as to make them roll upon one another, or other substances, by which they have been smoothed, some of which have been afterwards enclosed in stone, &c.

"Many shells would appear to have been lined with stone, and then the cavity filled up with sand. Many have been encased with stone and filled with the same, afterwards the shell has been destroyed, and left the cast in the stone almost loose.

"Some shells are turned into chalk. It would appear in all of the encrine kind, as also the Echinus, that after a mould had formed all around, and also in the Echinus, the shell filled up; that the shell had dissolved and crystallized again, and in a particular manner, for they break in flakes. This appears to be universally [the case] with all those substances."—P. lv.

Geological research, since Hunter's time, has confirmed his conclusion that the flat-tract, or valley, of the Thames, was once an area of the sea, or a vast estuary, receiving, however, in addition to remains of its own sea-inhabitants, occasional contributions, by a more ancient river, from some adjoining continent, in the form of great serpents, sea-turtles, singular quadrupeds, like the *Coryphodon, Pliolophus,* and *Hyracotherium,* of genera now unknown; and plants of a tropical character, such as the fruits of the Palms of the genus *Nipa,* which is allied to the Pandanus and cocoa-nut palm; of species of *Anona* or custard-apple; and of *Acaciæ,* which, although less decidedly tropical, imply a warm climate.

Permit me to refer to one other example of Hunter's special geological observations, made at a comparatively early period of his life, when he was serving, as surgeon, with the English army in Portugal. We have long known that the employment of his leisure and opportunities, in that capacity, was most exemplary to all young surgeons similarly circumstanced: the temptations to enjoy, in a fine and voluptuous climate, the hours not required in the routine of strict military duty are such as few resist: the conditions for devoting those leisure hours to special scientific pursuits, are generally anything but favourable or encouraging. But they in no degree abated Hunter's ardour in the pursuit of truth: nothing was suffered to impede his observations, dissections, experiments, and collections of natural history. His museum still shows the preparations he made of Portuguese lizards and other indigenous species, which he succeeded in bringing home, in 1763, and which formed, indeed, the nucleus of his great collection of comparative anatomy.

That Hunter, whilst with the army in Portugal, laid the foundation of his principles of physiology, and of the physiological treatment of disease and injury, finally set forth in his work 'On the Blood, Inflammation, and Gun-shot Wounds,' is part of the history of surgery.

Most of my physiological hearers may recollect that it was in a gentleman's garden in Portugal that Hunter made the experiment determining the possession of the sense of hearing in fishes, of which sense he believed that he had first discovered the organ in that class. But science has not hitherto known, or had any ground for surmising, that Hunter found time, and had the disposition and the perceptive faculty to note also, the geological phenomena of Portugal, and the deductive power to frame and store up conclusions as to the geological dynamics that had operated on the scene of his encampment. Yet it was from observations at this period of his life and in Portugal, that he derived his ideas of one of the modes in which a retiring sea acts upon an uprising continent, and also of the slow and gradual mode of that operation.

"The extensive flat tract of land in Portugal called Alentejo, shows," he writes, "evident signs upon its surface of having been covered by the sea. There is a vast extent of flat country going to Portalegra covered with loose gravel, apparently of considerable depth; and there are also considerable heights composed of such materials; but those composing heights are cemented together like plum-pudding stone, only the cement is not so strong; which cement was probably the cause of their retaining this situation and form.

"But the most striking evidence of the sea having once covered this tract, and afterwards having left it gradually, is the peculiar shape of the remains of those elevations of gravel; for it would appear that as the sea left their tops exposed, the pebbles were washed off by the motion of the surface of the water where this motion is greatest; and, as the sea subsided, the lower part of such risings, beyond the general surface or basis, were longer washed by it than the top; consequently more of the gravel was washed away, till at last they became of a pyramidal figure standing on their apex . . . . and all round, on the flat surface, is strewed the gravel washed off the rising part which now forms the inverted pyramids."

He adds, "If the sea was to leave the Isle of Wight, the Needles would exhibit something of this kind."—P. xvi.

The distinguished geologists who may have honoured this theatre by their presence, will need no other or better proof of Hunter's powers in his new character, as a pure geological observer, than the instance which I have just quoted.

Besides the aqueous causes which Hunter recognizes as operative in modifying the surface of the earth, exemplified by the effects of running water, as in valleys and river-courses, by the operation of a retiring sea upon a rising land, by deposition varied according to the different distances to which matters according to their size, &c. would be transported and spread over the sea-bottom, and by the action of the sea on coasts as moved by tides and winds—I would remark that, in addition to these Neptunian dynamics, Hunter does not overlook the agencies of the Plutonists:—

"Besides which [aqueous causes] there are volcanic eruptions taking place, which break the surface of the earth considerably, probably destroying the old and forming new: possibly the Straits of Gibraltar were formed from such a cause; the Straits between Dover and Calais; the west end of the Isle of Wight, broken off from the chalk hills that run through Dorsetshire; as also raising up considerable extent of the surface of the earth which is already formed; either raising up mountains on its surface, or islands, when such arise in the sea; afterwards increasing their height by scattering inflamed matter from its bowels on the surface; exposing substances rather than forming them; leaving (we may suppose) vast caverns underneath, in which are again, probably, formed native fossils. This may answer some material purpose in the natural economy of the earth, but it does not appear so systematic—not so much a general principle."—P. xviii.

"These may form mountains and valleys; or mountains may probably be formed, as has been supposed, by subterraneous heats raising water into steam, heaving up large tracts of surface, but which would hardly form such length of ridges of mountains for many hundred miles with such regularity as we find them; at least, the eruptions that now take place on the land do not produce such. Or whether the vast valleys are only so many parts sunk, which are equally explicable upon the appearance, but which are not to the present purpose."—P. xxii.

"In all of nature's operations we may observe that they always tend to destroy themselves. But there is, on the other hand, a restorative principle; it is like the hour-glass requiring being turned as soon as run down: but in the hour-glass we have not the principle of inversion arising out of the effect being completed, as we have in natural things; and indeed, in whatever way the raising of the bottom of the sea is accounted for, we must ultimately suppose such a principle; for if the bottom is raised by any such power underneath, either by steam or volcanic eruptions, which arise from the same principle, a space somewhere must be formed, into which the water will rush; and a repetition of them would bring the whole water towards the centre under the surface; therefore, from such a principle, the waters would be gradually losing on the surface, and equally require a restorative principle."—P. xxiii.

"As the fossils of the sea, or water-animals, can now only be found upon land, it is a proof that the sea was once there; and from this alone we may presume that where the sea now is, it was once land. This leads to two modes of the exposition of the earth; one, the sea leaving the land; and the other, the bottom of the sea rising up above the water by some convulsive motion of the earth at this part. I should be inclined to consider it in both views; probably great continents have been formed after the first mode, and islands after the second."—P. xlv.

"I formerly observed that earthquakes very probably raised islands; that on the surface of such there would be found shells, and in vast quantity, recent, dead, and fossilized. . . . This upraising of the bottom of the sea above the surface of the water, will also raise up along with it all the shell-fish that lay on the surface of the bottom, as also dead shells, and in the substance of the earth all the deeper-seated substances imbedded or enclosed in stone, chalk, clay, &c., which I have said constitutes the true fossil. This appears to be the state of the case on and in the Island of Ascension; the whole surface of this island is covered with shells, and some so perfect as to have their ligaments still adhering. There is, besides, a vast quantity of lava, and other volcanic matter; all of which shows it most probably arose in this way, because such recent alteration in the sea, so as to have exposed so much of its bottom, and so recently as to have the animal part of the shell still adhering; and the very name implies its rise[1]. I suspect that many of those shells found on land near the surface, on the tops of mountains, have been exposed in this way."—P. xlvii.

Finally, Hunter adverts to the agency of animal life in modifying and adding to the crust of the earth.

"Although a great part of the calcareous earth is undoubtedly of animal origin, yet the same cannot be said of the whole; for without relying only on those calcareous mountains and strata which do not exhibit traces of the animal kingdom, and which by some are therefore to be considered of a more ancient date, we find that several of the elements of the granite contain a portion of calcareous earth as a constituent principle, schorl, felspar, and even quartz.

"Now, if we allow the granite to have been formed prior to the animal creation, we must also allow that calcareous earth has not entirely originated from decomposed animal substances, because we find this earth entering into the composition of several elements of the granite. This does not, however, in the least militate against what is mentioned in this part of the paper; on the contrary, it appears scarcely to be doubted that chalk, &c., which contains shells and the like, has itself originated from decomposition of similar productions."—P. xliv.

Quartz consists of silex, and is not considered by the best analytical mineralogists naturally to contain lime: but many of the granitic

[1] [This is very ingenious; but the superstitious Spaniard had little thought of the geological causes of the island, when he discovered it on the evening of 'Ascension Day.']

minerals, as the schorl or black tourmaline, felspar and mica, do contain 'calcareous earth,' and 'apatite' contains it in combination with phosphoric acid. Hunter, with his usual caution, puts the antecedency of granite to the animal creation problematically: later observations of the formation of granitic minerals subsequent to fossiliferous sedimentary strata, have made it conceivable, if not probable, that, in parts of the earth's crust that have been subjected to such heat as has converted them into 'granite,' such fossilized remains of animals as the metamorphosed strata may have contained may have been reduced to the mere earthy principles of carbonates and phosphates of lime, which chemistry has detected in the granitic minerals cited by Hunter.

And now, in conclusion, to sum up the general principles which Hunter recognized as having been operative in modifying and producing the present condition of the surface of our planet, and in introducing and preserving the evidences of organized beings therein found;—first, he exemplifies the effects of running water, as in valleys and river-courses; secondly, the deposition of the matters so transported to the sea, noting the different distances to which such transported matters would be spread over the sea-bottom according to their size and other physical characters; thirdly, the erosive action of the sea on coasts, as moved by tides, currents, and winds; fourthly, the power and mode of operation of a retiring sea on a rising land; fifthly, igneous expansive force and volcanic eruptions; and sixthly, deposits through animal or organic agency.

These are recognized geological dynamics, operating in the actual system of things, strictly included in that class of causes, and agreeable with "our mode of reasoning," as Hunter terms it, which is, viz. "by supposing from the state of the earth as it is now, what must have taken place formerly."

Only in two instances, already referred to, does Hunter deviate from this strictly philosophic track: it is when he brings in the old hypothesis of a change in the inclination of the earth's axis to account for the presence of what he believed to be remains of tropical animals in the strata of cold or temperate climates; and where he alludes to the attractive power of a comet upon the mass of waters of the earth, or as having the power to add to that aqueous mass.

Other evidence, by fossil remains, of a warmer or more equable, and perhaps of both a warmer and more equable, climate having prevailed in the latitude of London, has been since abundantly obtained: and there are not wanting Fellows of the Geological Society who still, like Hunter, advocate a change in the ecliptic: but every accession to our knowledge of the local circumstances that influence local climates, and to our experience of the power which species of tropical generic types, of both plants and animals, have of not merely existing but flourishing in mild and equable climates—has tended to remove more and more the necessity for reference to a hypothetical change in the system of nature, in order to their intelligible explanation of the presence of fossil remains of a tropical physiognomy in one set of strata, or of those of an arctic character in another, both of which evidences abound in England, and testify to the range of change to which the climate of this now temperate latitude has, from whatever cause, been subject.

As to the igneous, expansive, upheaving cause of geological phenomena, Hunter, while admitting it into his category of geological forces, places it on a lower rank than the aqueous. Yet he duly appreciated and finely illustrated its power and scope of operation. And in this he rises above his contemporary, and some subsequent, geologists, who, though applying their intellectual powers exclusively to this branch of science, were unable to expand their minds to the reception of the evidences of the different kinds of dynamics that had acted, and were still acting, upon the earth, but ranged themselves into one or other of the rival factions of the 'Vulcanists' and 'Neptunists:' either contending, with Werner, that water alone had brought about the actual condition of the earth's surface, or, with Playfair, referring it as exclusively to the operation of fire.

Hunter admits the efficacy of the latter expansive, subterranean force, in "breaking the surface of the earth considerably, probably destroying the old and forming the new:—in separating lands formerly united, of which possible examples he cites—the straits of Dover and Gibraltar, and that which now divides the Isle of Wight from the opposite coast of England:" as "raising up a considerable extent of the surface of the earth, which is already formed," or "raising islands in the sea, and afterwards increasing their height by scattering inflamed matter on their surface;" thus "exposing mineral substances rather than forming them. . . . They may answer," he philosophically remarks, "some material purpose in the natural economy of the earth; but it does not appear so systematic—not so much on a general principle."

No Vulcanist could have more graphically or concisely illustrated the *modus operandi* of his favourite force, than Hunter does in the few pregnant sentences and instances above quoted.

And, in reference to the effect of igneous agency in upraising a considerable extent of the already formed surface of the earth, I cannot refrain here from adducing one of the many recorded instances of this geological operation which has taken place since the time of Hunter.

In 1822 the coast of Chili was raised by an earthquake, the shock of which was felt simultaneously through a space of 1200 miles, from north to south. St. Jago, Valparaiso, and other towns were much injured by that great commotion.

The shores of the Bay of Concepçion were similarly affected during the great earthquake of February 20th, 1835. Mr. Darwin, who felt the shock, estimates the upheaval of the land round the bay at two or three feet. At the island of S. Maria, about 30 miles distant, "Captain FitzRoy found beds of putrid mussel-shells, still adhering to the rocks ten feet above high-water mark: the inhabitants had formerly dived at low-water spring-tides for these shells." But the elevating force which operates more gradually, and without such violence, is not less important, and its effects are appreciable within the comparatively restricted period of human history. Thus it has been determined by successive experimental observations that the shores of the Baltic are rising at the estimated rate of four feet in a century. Ancient beaches extending along certain parts of the British coast, at elevations varying from ten to one hundred feet above the present sea-level, attest the upraising of such 'extents of the surface of the earth.'

Hunter by no means exaggerates the effects of the igneous or elevating force. He perhaps failed to comprehend its full influence in repeated operations during a vast period of time. He hesitated, *e. g.*, in applying it to the upheaval of such ridges of mountains as had been traced extending with a certain regularity for many hundred miles. "At least," he says, "the eruptions that now take place on the land do not produce such." It is easy to conceive, however, what would be the result of a succession of such lifts as have been observed to operate upon the base of the Andes in our own times, if continued through the 'many thousand centuries' that Hunter so often appeals to. Geology, indeed, now finds no numerical term adequate to embody the idea of time, which the contemplation of its phenomena forces on the mind.

With regard to the agency of animal life in forming or altering the earth's crust, Hunter, by virtue of his comparative anatomy and physiology, was, perhaps, the best able of any philosopher in his day to appreciate this now generally recognized geological force.

Although unaided by such microscopes as have revealed to Ehrenberg and others the animalcular origin of immense tracts of calcareous and siliceous earth, Hunter, after showing that the earthy materials of the skeletons of many animals, and especially of shell-fishes, star-fishes, and zoophytes, were the same earth as composed part of the globe, and as imperishable as such earth, boldly affirms that "a large portion of the globe is indebted to animals for such calcareous earth," and concludes by saying, "and indeed many of our islands are no more than superstructures of coral." But recognizing, as Hunter did, the different causes of geological phenomena, which later observers have established, he returns to the aqueous ones, in all their modes, with the power of solution, ... as the principal and most widely diffused power;" and most beautifully and truly defines them as being, "although not the sole formers, yet the regulators of the formation, of the surface of this globe."

The chief dynamical cause of change of the earth's surface which has been determined, since the time of Hunter, in addition to those which he recognized, is that of water in its frozen state. The disintegrating power of water in passing from the fluid to the solid state, though slow, is irresistible; and is considerable in every latitude where the temperature falls below the freezing-point; the operation of masses of ice or glaciers is more conspicuous and violent; but its sphere is limited in comparison with those of the great aqueous and igneous causes to which Hunter refers. The appearances which glacial action has left on many parts of the earth's surface were amongst the most remarkable and problematical, until at length satisfactorily explained by the observations, experiments, and calculations of some of the ablest geologists, profoundest mathematicians, and most enterprising voyagers at the present day.

The surface of the earth is affected by the movements of great ice-masses or glaciers on land, and by the floating masses or icebergs at sea.

"The agency of glaciers," says Sir C. Lyell, "in producing permanent geological change, consists partly in their power of transporting gravel, sand, and huge stones to great distances, and partly in the smoothing, polishing, and scoring of their rocky channels, and the boundary walls of the valleys through which they pass." The stones carried along and deposited by the glaciers are called the 'moraines.' There is always one line of blocks on each side or edge of the icy stream, and often in the middle, arranged in long ridges several yards high: the latter medial moraines are due to the confluence of tributary glaciers. This characteristic arrangement, or rather derangement, of parts of the earth's surface by the movement of ice, with the scoring and polishing marks of its transit, serves to indicate the former actions of glaciers in localities where they have never been known in the memory of man, and where the present climate is unsuited to their formation.

In arctic and antarctic latitudes, vast masses of ice are annually detached from the shores, and float off with more or less of the mineral matter of such shores. Scoresby counted 500 of these bergs drifting along in latitudes 69° and 70° N., which rose above the surface from the height of 100 to 200 feet, and measured some of them a mile in circumference. Many of them were loaded with beds of earth, and rock of such thickness that the weight was conjectured to be from 50,000 to 100,000 tons. Specimens of the rocks were obtained, and among them were granite, gneiss, mica-schist, clay-slate, felspar, and green-stone. They float to the more temperate latitudes, gradually melt, and let drop their mineral ballast to the bottom of the sea.

Sir James C. Ross, in his antarctic voyage, saw multitudes of icebergs transporting stones and rocks of various sizes, in high southern latitudes. In the voyage of antarctic discovery in 1839, amongst the numerous floating ice-masses, a dark-coloured angular mass of rock was seen imbedded in an iceberg drifting along in mid-ocean in lat. 61° S. That part of the rock which was visible was about twelve feet in height, and from five to six in width, but the dark colour of the surrounding ice indicated that much more of the stone was concealed. This iceberg was between 250 and 300 feet high, and was no less than 1400 miles from any known land. At what distance from its parent cliff that boulder rock was dropped to the sea-bottom is unknown.

The great boulder-stone in the valley near Derwentwater, will be familiar to all who have visited that beautiful part of the lake district. There is abundant evidence that the whole of that district was formerly covered by the sea. Ancient icebergs then floated over the submerged land of that latitude and longitude, as now over the same latitude, but in a different longitude, which then, perhaps, was dry land.

The 'boulder-stone,' as it is called *par excellence*, is one of countless similar but smaller erratics, which by their distribution over the surface of my own native county and the adjoining ones, clearly indicate the course of the currents that bore along the ancient icebergs which dropped them as they floated and melted over that old sea-bottom.

To appreciate the extent of geological change produced by the annual operation of ice in the form of glaciers and bergs, one must endeavour to multiply the observed approximate results of one year, by the countless thousands of years during which geology teaches that such glacial action has been going on.

I must not close this brief notice of a geological dynamic, unknown to Hunter, without alluding to the property of ice, especially as blended with earth and forming frozen-soil, in the preservation of animal bodies, and of the evidence which the nature of those animals, as being specifically different from any now in being, has yielded of the vast lapse of time during which such soil has been frozen, and the cause of glaciers and icebergs has been in operation, in the latitudes where such frozen animals have been found. To the comparative anatomist these phenomena are of peculiar interest and importance, since by this action of extreme cold, the soft-parts, integuments, hair, bristles, and other epidermal coverings have been preserved, to testify, in addition to the bones and teeth, as to the specific characters and peculiar habits of those extinct species.

Perhaps the greatest and most fruitful principle in the sciences of Geology and Palæontology which has been established since Hunter's time, is that of the limitation of particular organic fossils to particular mineral strata, and the regular order of succession of such fossiliferous strata.

This great discovery was made by an Englishman, and a contemporary of Hunter, though a much younger man—Mr. William Smith, justly entitled the Father of English Geology, whose personal acquaintance I have been honoured and favoured to make, a circumstance which I shall ever prize amongst my most cherished recollections.

Whilst the tenets of the rival schools of Freyberg and Edinburgh were being warmly espoused by devoted partisans, the labours tending to the solution of the dispute of the young land-surveyor were as little known as those of the great physiologist. But William Smith, fortunately for science and his own repute, published, in 1790, his 'Tabular View of the British Strata,' and their 'Identification by their peculiar organized Fossils.' This tract seems never to have fallen in Hunter's way. Smith prosecuted his geological investigations uninterruptedly until, in 1815, he had completed a Geological Map of all England.

Contemporaneously with the labours of William Smith, were those of Cuvier and Brongniart. The extensive, minute and exact knowledge possessed by Cuvier of Comparative Anatomy—especially Osteology—and of Natural History, enabled and emboldened him to speak decidedly as to the specific distinction, and of the extinction, of the vertebrated fossil remains submitted to his examination. Lamarck was able to enunciate the same important conclusions as to the fossil shells. The combined labours of the above great luminaries of the School of Paris, threw the same clear light on the laws of superposition and the characteristic fossil remains of the tertiary series of France, which William Smith's single-handed labours had effected for the secondary formations of England.

These independent discoveries—these undesigned coincidences of results of inductive research,—establish great natural truths on the unassailable and eternal basis of truth. Cuvier's labours were more particularly characterized by the rigid character of his demonstrations of the distinction of the fossil remains from the known existing species, and by the laws which he laid down for the guidance of his successors in that field of inquiry.

It has been well remarked, that no period could have been more fortunate for the discovery in the immediate neighbourhood of Paris of a rich store of well-preserved fossils, than the commencement of the present century; for at no former era had Natural History and Comparative Anatomy been more extensively and successfully studied at the Jardin des Plantes.

The labours of Cuvier in Comparative Osteology, and of Lamarck in recent and fossil Conchology, had raised these departments of study to a rank far above that which they had previously attained. Their investigations had eventually a powerful effect in dispelling the illusion which had long prevailed, but from which Hunter was free, concerning the absence of analogy between the ancient and modern states of our planet.

A close comparison of the recent and fossil species, and the inferences drawn in regard to their habits, accustomed the geologist to contemplate the earth as having been at successive periods the dwelling-place of animals and plants of different races, some terrestrial and others aquatic—some fitted to live in seas, others in the waters of lakes and rivers.

By the consideration of these topics, the mind was slowly and insensibly withdrawn from imaginary pictures of catastrophes and chaotic confusion, such as had haunted the imagination of the early cosmogonists. Numerous proofs were discovered of the tranquil deposition of sedimentary matter, and the slow and successive development of organic life.

The application of the binomial nomenclature of Linnæus to the animals indicated by fossil remains, and especially of the same generic names to the fossils and their living congeners, was an important step towards familiarizing the mind with the idea of the identity and unity of the mundane system in distant eras. "It was an acknowledgement," as Lyell well says, "that part, at least, of the ancient memorials of Nature were written in a living language." The growing importance of the Natural History and anatomical determination of fossil organic remains may be pointed out as the characteristic feature of the progress of the science during the present century.

This branch of knowledge has not only become an instrument of great utility in geological classification, but it has added largely to the facts of Comparative Anatomy and to the physiological relations of modified parts and organs to the peculiar habits of extinct species; and it is continuing daily to unfold new data for grand and enlarged views respecting the former changes of the earth.

Zoology has gained an immense accession of subjects through the determination of the nature and affinities of extinct animals, and much further and truer insight has been carried into the natural arrangement and subdivision of the classes of animals since palæontology expanded our survey of them.

The knowledge of the type or fundamental pattern of certain systems of organs, *e. g.*, the framework of the Vertebrata and the teeth of the Mammalia, has been advanced by the more frequent and closer adherence to such type discovered in extinct animals, and thus the highest aim of the zoologist has been greatly promoted by palæontology.

By this science the law of the geographical distribution of animals, as deduced from existing species, is shown to have been in force during periods of time long antecedent to human history, or to any evidence of human existence; and yet, in relation to the whole known period of life-phenomena upon this planet, to have been a comparatively recent result of geological forces determining the present configuration and position of continents. Hereby palæontology throws light upon a most interesting branch of geographical science, that, viz., which relates to former configurations of the earth's surface, and to other dispositions of land and sea than prevail at the present day.

Finally, palæontology has yielded the most important facts to the highest range of knowledge to which the human intellect aspires. It teaches that the globe allotted to man has revolved in its orbit through a period of time so vast, that the mind, in the endeavour to realize it, is strained by an effort like that by which it strives to conceive the space dividing the solar system from the most distant nebulæ.

Palæontology has shown that, from the inconceivably remote period of the deposition of the Cambrian rocks, the earth has been vivified by the sun's light and heat, has been fertilized by refreshing showers, and washed by tidal waves; that the ocean not only moved in orderly oscillations regulated, as now, by sun and moon, but was rippled and agitated by winds and storms; that the atmosphere, besides these movements, was healthily influenced by clouds and vapours, rising, condensing, and falling in ceaseless circulation. With these conditions of life, palæontology demonstrates that life has been enjoyed during the same countless thousands of years; and that with life, from the beginning, there has been death. The earliest testimony of the living thing, whether coral, crust, or shell, in the oldest fossiliferous rock, is at the same time proof that it died. At no period does it appear that the gift of life has been monopolized by contemporary individuals through a stagnant sameness of untold time, but it has been handed down from generation to generation, and successively enjoyed by the countless thousands that constitute the species. Palæontology further teaches, that not only the individual, but the species perishes; that as death is balanced by generation, so extinction has been concomitant with the creative power which has continued to provide a succession of species; and furthermore, that, as regards the various forms of life which this planet has supported, there has been "an advance and progress in the main." Thus we learn, that the creative force has not deserted the earth during any of the epochs of geological time that have succeeded to the first manifestation of such force; and that, in respect to no one class of animals, has the operation of that force been limited to one geological epoch; and perhaps the most important and significant result of palæontological research has been the establishment of the axiom of *the continuous operation of the ordained becoming of new species of living things.*

Amongst the circumstances that have most conduced to extend a knowledge of the nature of the changes in the crust of the earth and its inhabitants since Hunter's philosophical attempt to comprehend and explain them, must be cited the establishment, in 1807, of the Geological Society of London. By the labours of the distinguished founders and early members of that Society, Wollaston, Greenough, Horner, De la Beche, Fitton, Conybeare, Sedgwick, and Buckland, Geology was soon rescued from the imputation of being a dangerous, or at best a visionary, pursuit. By their worthy successors, so numerous now that to particularize might seem invidious, but amongst whom common consent would name with honour Murchison, Phillips, and Lyell, and by the well-organized Geological Survey of Great Britain, the combined Sciences of Geology and Palæontology have been most surely and rapidly advanced; and I cannot conclude this sketch of the leading steps of that advance, made more especially in England since the time of Hunter, than in the eloquent language of the most philosophical historian of the progress of the combined Sciences which owe so much to his own original labours.

"Never, perhaps, did any science, with the exception of Astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow, but never-ending, fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy; to trace the same system through various transformations—to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research.

"By the geometer were measured the regions of space, and the relative distances of the heavenly bodies;—by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events—a succession of phenomena in the animate and inanimate worlds—signs which convey to our minds more definite ideas than figures can do of the immensity of time.

"Whether our investigation of the earth's history, structure, and successive inhabitants will eventually be productive of as great practical benefits to mankind as a knowledge of the distant heavens, must remain for the decision of posterity. It was not till Astronomy had been enriched by the observations of many centuries, and had made its way against popular prejudices to the establishment of a sound theory, that its application to the useful arts was most conspicuous. The cultivation of Geology began at a later period; and in every step which it has hitherto made towards sound theoretical principles, it has had to contend against the most violent prepossessions. The practical advantages already derived from it have not been inconsiderable: but our generalizations are yet imperfect, and they who come after us may be expected to reap the most valuable fruits of our labour. Meanwhile, the charm of first discovery is our own; and, as we explore this magnificent field of inquiry, the sentiment of a great historian of our times may continually be present to our minds, that 'he who calls what has vanished back again into being, enjoys a bliss like that of creating[1].'"

[[1] Lyell, 'Principles of Geology.']

[OBSERVATIONS ON PHYTOLOGY.]

OBSERVATIONS AND EXPERIMENTS ON THE VEGETABLE ECONOMY[1].

Of Vegetable Life.—The life of a vegetable comes under the same definition with that of an animal. It is a power of action within the vegetable itself, independent of any mechanical power whatever. For, although impulse, which can produce a mechanical effect, may be a cause of that power being brought into action, yet it can be brought into action by causes that are not mechanical—causes that cannot produce any mechanical effect whatever, nor arise from any. A mechanical impulse may produce action within the vegetable, yet the effect is not mechanical: that is, although the body impelling may lose some of its power by this impulse, yet the body impelled [or stimulated] has not acquired the same power, which would be mechanical; but it may exert a power much greater or less according to circumstances, which power was not received from the impelling body, nor was the power in the impelling body lessened in proportion to the action of the body receiving the impulse [or stimulus].

In speaking of vegetable life, and the actions arising from it, the same language is applicable as in speaking of the operations of an animal.

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[1] [The manuscript volume containing these 'Observations,' &c., was liberally presented to me, in May 1860, by Ed. Rushworth, Esq., nephew and executor of Captain Sir Everard Home, Bart., R.N.: it is a small thin quarto bound in parchment. On the inside of the back is the following memorandum in Capt. Sir E. Home's handwriting:—"The handwriting of Mr. Bell, Mr. Hunter, Everard Home, and others. Two pages of index. The volume wants pages 20, 29, 30, 77, 78; then perfect to page 164; after which there are two leaves numbered 169 and 170, and 175 and 176. There is a strip of paper stuck in between pages 34 and 35, another between pages 38 and 39, between 52 and 53, and one on 53; between 96 and 97, one on 176, and two on the cover inside.—E. H., Sept. 10th, 1829."

These intercalated strips are, with one exception, in the handwriting of John Hunter: the exception is the letter from Dr. Solander (p. 355), in reply to a question by Hunter, as to climbing, sleeping and moving plants.

The MS. on the left-hand pages is by the amanuensis; that on the opposite pages is in the handwriting of Hunter, supplementing the text, which also contains interlineations, corrections, and erasures by Hunter's hand.

A copy of this volume was presented by Capt. Sir E. Home, Bart., to the Royal College of Surgeons, in 1829.]

It is expressive of actions whose causes and effects are very similar, although the mode of performing them may not be similar.

Of the Suspension of the Actions of Vegetables.—The actions of a vegetable depend on the living principle. We see those actions suspended, although the living power is existing; and probably this power can lie much longer inactive in the vegetable than in any animal, its own existence not depending so immediately upon action in the vegetable as in the animal; but this varies very considerably in the different classes of vegetables, as also in the different classes of animals. However, it is probable that the vegetable, which can the least bear a suspension of its actions, can do so more than the animal, which can bear it longest. I am not alluding here to those natural suspensions of actions which appear to be a necessary part of their economy, as where a plant cannot be active during two seasons without an interruption to the vigorous actions, but to those suspensions of action arising from some violence, such as transplanting, or probably disease. Trees shall have their actions suspended for one, two, or three seasons, but be still living, and shall die at last.

I planted some Scotch Firs in the month of July, 1772, when the shoot was full-grown. In the following spring one of them did not send out fresh shoots, although the buds were fresh and the whole was green; it remained in this state all the summer: the winter following it appeared just the same as in the preceding winter, viz. the last shoot, which was a year and a half old, appeared like those of the last spring's growth in other firs; the spring following, 1774, viz. two years, it was stationary, and kept fresh as in the preceding spring, but it died in the summer. Here was life sustained without action for two years; but as it had not powers to act, the tree lost its powers of life, not being able to live under a longer suspension of its action.

On the other hand, we find that in many vegetables, although their powers are weak, yet their actions are not suspended when the proper season is calling them forth; but often these necessary actions are more than the powers are capable either of perfecting or continuing. If the necessity to act is not greater than the power, then they go on well; but if the necessity to act is greater than the power, then they become weak, and perhaps cannot even support life, and they die. This is seen in very hot weather in summer, when trees, &c. die through heat, although well-watered. It is still more remarkable in newly planted trees, where the living powers are rendered much weaker than at another time; for if the weather becomes hot, and continues long so, they certainly die. We may see them send forth their young shoots and leaves, but those shall die upon the approach of the too hot weather;

and if mild or cold weather come on, they shall begin to shoot out stalks afresh, as also leaves. Such trees (if of value) should be sheltered from the sun for the first summer, especially if the heat is considerable.

In every vegetable there is a certain power of action. In some, as the Blackberry-bush, it is much more than in others.

Trees, when they have become very much weakened by a long hard frost or winter, shall in the spring begin to shoot out their buds; but when the weather becomes warm, they are then not able to act equal to the heat, and they die. This sometimes takes place in the whole plant, in others only in part, often in one or more branches; but as the last shoots of plants are the weakest, we find this effect mostly in those. In hard winters the last shoots may die, and we shall see the living part next to the dead shoot out its leaves; but as the heat of the weather advances, those leaves shall fade and wither away, and those lower on the vigorous stalk or branch below shall live. If such trees are put into a hothouse to be forced, this effect will be more certain and extensive.

More striking, I have seen fig-trees in tubs suffer very severely from a hard winter in their last shoots, and those that were put into a hothouse began to vegetate in those last shoots, but both shoot and leaves died, while those leaves from the same shoot below lived. In those trees that were not exposed to a heat above their powers, but were allowed gradually to recover powers as they recovered action, the same effect did not take place.

[*Separate Note on the same subject.*]—I know a Scotch Fir which was transplanted in July 1772, after it had made that year's shoot; the spring following it had not the least sign of active life, and was supposed to be beyond recovery, although on removing the bark at any part it was found fresh. In the month of July, 1773, it began to shoot, and continued to grow. The same thing happened to a White Thorn. A Spanish Broom was under the same circumstances, and was attended with the same effects.

On the other hand, we shall find that the actions of life shall be very weak for a season or two, and die at last; this is a very common thing with new planted trees, and probably with everything that is newly planted. Some, however, do not remain long in this inactive state, but either recover or die; as many annual plants, and those that live two or three years, *e. g.* cabbages.

Of the Movement of the Sap.—The juice of vegetables, commonly called sap, can either ascend directly, pass laterally or obliquely. Thus if we bark a tree nearly all round, leaving only a little part, the juice of the plant, to supply the tree above, passes directly up through this part; and, as it supplies the whole above, it must then diverge in all directions. This is best seen, however, in those trees which die to the heart when barked. But in others it might be supposed that the body of the tree carried up its juice beyond the barked part, as in many trees, the Apple, Pear, &c. From this property the juice can be made to take any direction. If a straight stem of a tree has a piece of bark removed in an oblique direction, which, when carried on, runs into the spiral, the sap will be conducted along the remaining bark, which, of course, is also spiral (fig. 1, *a b*); and these spiral turns may go several times round; but this is as much as many trees can do, and more than some can bear. In those whose wood does not die when barked, the spiral barking may go round several times; for we may suppose that the wood of the tree conducts the juice, when barked in this way, as well as when barked all round: but in those whose wood dies to the centre, the bark must carry the whole juice, excepting the little bit of wood that is covered, which may carry some of the juice; but the whole or the best part must go along the spiral bark. And as this in such is not sufficient if the turns are many, it is necessary [in the experiment] to go at first only once round the first year, then once more the second year, and so on. From which it would appear that the parts acquired a facility in conducting the juice; or rather that the last year's bark on this spiral part was so formed as to conduct the juice better than the bark at large.

Of the Bark of Trees.—The bark of trees is that external covering which may be said to have no sap in it, and hardly has any particular arrangement of its parts or substance.

This part of a tree may be divided into two kinds respecting permanency; the first is when it is never changed, and the other where it is. In the first, as this part of the tree does not grow in the same proportion as the tree which it covers, there must be some provision in nature for this; we find in such that the bark cracks, and those cracks at their bottom are filled up with new bark, probably from the sides of the cracks.

The bark appears to be one of the most essential parts of the tree—it appears to be the life of the tree; for, first, without it they cannot live; and, secondly, it is the immediate cause of growth, not only in the part it covers,—or in other words, each part receiving its increase from that part of the bark which covers it,—but the bark has a sympathizing communication through the whole tree; so that the tree shall be variously affected, just as the bark of any particular part shall be affected.

Of the Barking of Trees.—When a tree or a branch is barked in any one part half round or more, the remaining bark in the circle forms a much thicker layer than it would otherwise have done, thicker than anywhere else on the same trunk or branch of the tree; it is perhaps equal in amount to a whole circle of the ordinary layer of the same trunk or branch. The stimulus of growth is increased by a real weakness being produced.

Upon the same principle, when a tree or branch is barked all round, the cut-edge nearest to the extremity of the tree or branch, close to the barked part (fig. 2, *b*), grows faster or thicker than any other part of the same tree or branch (*c*). But this increased growth close to the barked part, is, I believe, only in those trees which live at the barked part (*a*); but in those (as the Laburnum), which only live that season in which they are barked, the growth of the part beyond where the bark is taken off is less near to the part than it is further on.

Fig. 1.

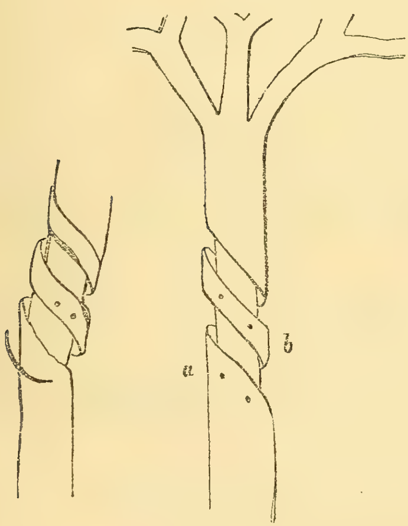
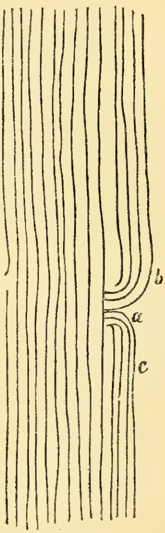


Fig. 2.



An apple-tree barked spirally about once and a half round (fig. 1), threw out many branches below the barked part, but near it (as at *a*), also in the spiral between the spiral turns of the barked part (*b*). This is upon the same principle; for the unbarked part has no sensation of the part above, therefore it sends out shoots.

Pear-trees, when barked, often throw out a new bark from the wood in different parts of the barked part. The same thing takes place in the Hazel, which shows that the surface of the barked part keeps alive.

The effect that the removal of the bark has upon trees is twofold: one producing death in that part, as deep as the centre or pith; the other death only a little way beneath the surface, like an exposed surface of a bone: and I believe that, in some, life is retained on the very surface, as is often seen in the Pear-tree.

If the barking be only partial, little or no effect upon the tree in general is produced, whatever be the influence on the part barked; for if the barked part dies to the centre, the remaining bark on the same plane is sufficient to carry on the communication between the two parts of the tree, viz. the root with the part barked, and the tree beyond the part barked. But if the tree be barked all round, two very different and material effects take place in the two degrees of influence; for the tree that dies from the surface to the centre, now dies all round to the centre, and we find that every part of the tree beyond the barked part dies, although not immediately; but, in the other case, the wood only dies a small depth from the surface all round, and the parts beyond the barked part do not die, but produce a number of new parts.

I have said that in the tree which dies to the centre when barked all round, the parts beyond do not lose their life immediately; but this happens sooner or later, according to circumstances, at least so far as my experiments have yet gone. If the bark be taken off in the autumn, the parts beyond appear to die sooner than when the bark is taken off in the spring experiment.

In the month of September 1779 I took off a circular piece of bark from two branches of a Laburnum, with the view to see if the parts beyond lived the first year. April 1780 they began to shoot forth, but they both died. From the circumstance of their beginning to throw out leaves, &c., we must allow that they had lived through the winter, and probably this was because they had at this time little or no action to perform.

Experiment second, April 1780: on the same Laburnum I took off a circular piece of bark from a branch, and it shot forth its leaves, flowers, &c. as strongly as in any of the other branches. In March 1781 it began to shoot forth its leaves and flowers a second time, but they were both very small; and in the autumn it visibly died.

Experiment third.—The same experiment was made upon another Laburnum, in March 1781 and was attended with nearly the same circumstances; the only difference being that this was rather more lively in all its actions.

Experiment fourth.—At the same time, viz. March, the same experiment was made upon a branch of a Walnut-tree, which threw out leaves, &c., but lost the leaves by the latter end of August, which was much sooner than the other branches did, and it became dead that winter; so it did not live so long as the Laburnums. So far as to the effects of barking all round upon the Laburnum and Walnut.

In those trees which live at the barked part, and therefore live beyond the part barked, nothing particular happens respecting the mode of throwing out their leaves, branches, or flowers; but other circumstances take place. The Scotch Fir, Plum, Pear, Apple, are not killed by being barked all round; but a very curious circumstance respecting the vegetable economy takes place, the facts relative to which I shall now describe.

In those trees which do not die upon being barked, we see the three following facts:—first, I find that, if barked all round, the part beyond grows in general as fast as if it had not been barked, while the part between the root and barked part grows but very little; so that we shall often see a thick part above, and it shall become small all at once: secondly, all that part of the tree above the circular barked part (fig. 2, *a*), not only grows as if nothing had been done, but it grows faster in thickness near to the barked part (fig. 2, *b*) than in any other part, and much faster than if it had not been barked: and thirdly, the increase of the new layers over the barked surface to cover it, is much thicker, and makes a much quicker progress on that side beyond the barked part (ib. *b*) than on the side next to the root (ib. *c*); indeed, it hardly makes any progress at this part at all.

The foregoing facts explain much more of the vegetable economy than any other circumstance attending vegetables. We may first observe, from the circumstance of the tree dying, but not immediately, beyond the barked part, in consequence of its dying at the barked part, that the nourishment of the tree is carried through the wood and not by the bark (at least alone). But the three facts last mentioned, respecting the growth of the part beyond the barked part in those which do not die at the barked part, are still more curious; for the disproportion in the growth of the two parts is a very remarkable fact. It shows that by barking a tree all round, the intelligence between the two parts is cut off, although the nourishment is carried on; that the part beyond and near to the mischief is sensible of such an injury, and sets to work to repair it: and that it should be sensible of this is evident; because from this and the consequences of it, viz. the second and third observations, the loss is repaired, and the intention of this repair is to support all the parts above. Therefore we may assert that the part of the tree beyond the barked part is conscious of the injury, conscious of a part rendered weak, and the stimulus of the necessity of growth takes place here. Or it may be put in this light: the part near or close to the barked part is conscious of the injury done on one side, and conscious of what is to be supported on the other, therefore it sets to work accordingly, that it may be able to do the last [support the parts above[1]].

The part between the root and the barked part growing but very little, is also easily explained: for by admitting that the communication between the two parts is cut off, then it is only reversing the above theory, viz. its not being conscious of any part beyond it, as if it had been cut quite through, as was mentioned in page [345].

April 1775 I made the following experiment:—I slit the bark of a branch of a Scotch Fir for about two inches in length, and separated the bark from the wood all round, and put a piece of card round between the bark and the wood to keep them separate,—the slits allowing me to pass the card all round. This branch shot out as long shoots as any of the others in the same circle, but it died in the winter.

I did the same with a Laburnum: one of the slits of the bark formed wood in its inner surface, and the branch lived.

The same with a Lilac. The flowers of this branch did not blow so soon as those on the other branches, nor did they come to perfection. The leaves were of a paler green than those of the other branches.

Of the Growth of Trees.—Trees and shrubs grow in thickness by a new layer of wood being laid every year on the outside of the last year's, immediately on the inside of the bark; and, as the new layer is at first but slightly attached to the last year's layer, but every year becomes firmer and firmer in its attachment, I find that, when the branches are cut off in the autumn, after this outer layer is completely formed, such layer, in the stem, will not attach itself to the last year's layer until the following year; and even then it will not be attached strongly, because this year's shoots are not such as give great influence to the action of the stem.

As wood grows by a new layer being formed every summer on the surface of the old, and as each layer is several months in forming, the first formed part of every layer has the whole summer to perfect itself in, and so on less and less, as the succeeding parts are later and later in forming; so that the last formed part has but little time in the summer to become good wood; therefore each layer is made up of wood

[1] [This paragraph is eminently characteristic of Hunter's peculiar mode of physiological thought, and of his tendency to personify phenomena. The greater growth above the barked part is due to the arrest, at that part, of the descending nutritive currents of the carbonized sap.]

of different degrees of goodness. This is evident in the wood itself, and shows itself upon almost every occasion; for instance, cut a piece of wood across, and look upon the cut end, you will find the inner part of each layer the hardest and most solid to the eye, but the exterior part is porous, and if it be Fir, we find that it is fuller of rosin. The same appearance takes place upon a longitudinal view of each layer. This is not only seen in sound wood, but it is seen most plainly in the decay of wood, for we find that the outer part of each circle or layer is soonest rotten, and becomes hollow while the other stands.

On the 1st of August I observed that the present summer's growth of a Fir and of a Laburnum had become the external layer of wood of the tree; and what now came off in the form of bark, was a new layer of wood that had begun to form, which was of a pale green covered by two cuticles,—one, an outer, thin and brown, the other thicker and green. The outer surface of the last layer of wood was of a very pale green, which could be pushed off with one's nail. This new beginning layer of wood, I apprehend, is formed by a second growth, which trees commonly have.

In trees, the first shoot or stalk is always better wood than the second, the second better than the third, and so on, even of the same age. Thus, if we compare the first year's growth of a sucker, or that from a seed, with the second year's growth of another sucker, or from a seed, we shall find that the wood of the first year is much heavier and much tougher.

The stem is always better wood than the branches, even of the same age; so that the branches upon the whole are the worst of all. Thus if we compare a branch of any given age with the stem of the same age, we shall find a greater difference than between any of the branches.

The branch from a branch is worse wood than the branch from a stem, and so on; so that every succeeding year's wood is worse than the preceding.

Every branch may be reckoned a stem, or a principal, to the shoot it gives off; and in this view it is similar to the stem with its second, third, &c. shoots; and it may be reckoned a principal to its own branches, and is always better wood. The reason of this is evident, for the strength or goodness of the wood must be in proportion to what it has to do, or to support.

The stem has always the strongest wood where it gives off a natural successive branch; because, there, it has not only to support the tree equally with every other part of the stem, but it has to support the weight, motion, &c. of that branch.

Both the stem and the branch grow in thickness in proportion to the quantity and size of the branches beyond, viz. in proportion to the support wanted: therefore, if the branches are cut off from the trunk, or the smaller branches from a larger one, the trunk or branch so deprived of their dependents will still only grow in proportion to the decreased dependents.

The leaves of trees increase the necessity of the growth of the stem or trunk, without the necessity of increasing the number and size of the branches; so that the stem and the branches do not bear a due proportion to one another, but the stem does to the leaves and branches taken together.

Whenever a tree, or probably any plant, throws out strong suckers, or throws out new, strong, and healthy branches from the stem, be assured that the top is not so strong as the bottom; and that there is not an equal quantity of life or powers of growth in both. It is on this principle that those plants which are continued by suckers, produce the suckers or new stem; for if the old one was continued in full force, no suckers would arise. This appears to be the case with partly full-grown trees. A tree beyond a certain period begins to make shorter shoots, and this goes on in a kind of inverse ratio to its age; but if a lateral branch shoot out from the stem, it grows luxuriantly like a young shoot. Thus, when we see trees lopped up to near the top, the side-shoots are strong, while the continued shoots of the top branches are weak, just the reverse of a young tree.

The lower a new branch arises the stronger it is, and in the same proportion larger, from which principle a sucker is the strongest wood, and is the longest and thickest.

The branches of a tree on that side where there is something obnoxious to their growth, such as high wind, too much sun, sea air, &c., do not grow so strongly as they do on the other side of the same tree. I suspect that this failure does not arise entirely from the branch itself, but that the affected side of the tree has not powers equal to the opposite side, so as to give sufficient nourishment to the branch.

The great growth of every shoot is an elongation of the top; but, besides this, the part of the shoot that is already formed grows in all its parts; but that is only in proportion to the age of the part of the shoot; for the last-formed part increases most in itself, and gradually less and less so to the setting on of the shoot, so that every part of the shoot has always lost its power of growth within itself in proportion to its age. This is the case with the fir, asparagus, Duke of Argyle's tea [*Lycium barbarum*, L.].

The greatest growth among all the different shoots of a plant being the top one, the next degree is in the branch immediately under the top shoot; and the growth of the top [or end] shoots of the branches decreases downwards, but the top shoot of each branch is always longer than the side shoots of the same branch. The top shoot is always perpendicular and highest, or most so of any; and this falling off from the perpendicular towards the horizontal, becomes gradually more and more so downwards to the lowest branch*.

Qu. Is it owing to this perpendicular position, or to the greater height, of the shoot, that the growth is greater?

Exp.—A Scotch Fir had its top or leading shoot cut off: it had four principal second shoots or side branches immediately under the top shoot. On the 1st of July I tied up one of these four side branches; in three days that young growing shoot became perpendicular, and in the same line with the stock on which it grew, and it had also grown an inch longer than any of the young shoots upon the other three side branches; so that it got the impression of the leading shoot.

From the above principle in growth, we should suppose that the greatest powers were at the top, and [that they] become weaker and weaker downwards; but we find that not to be the case. It is not strength of action, but it is a principle of action: we may as well say that the powers in a man's legs are greater than in any other part, because they grow longer; but we know their powers from this cause are weaker than other parts; and we also know that the quickest and longest growing shoot is the weakest in the vegetable, owing to the same causes. For we may observe that, when anything affects the general health of a vegetable, such as transplanting, severe winter, &c., it is always the top shoot that shows signs of weakness most; and upon the same principle that the extremities in animals are weaker in their living powers: and we may observe that although branches do not form such long shoots as the top, yet they are first in action in the spring.

When trees begin to throw out their leaves in the spring, or rather form new shoots, it is always on their lower branches first, and in gradual and regular succession upwards; but still the upper will make the greatest progress, having more the principle of growth. Also, if a tree be newly planted, and does not take kindly to its new situation and is weak, we find that the most vigorous parts are its lower branches, strength decreasing upwards to the top shoot, which is the weakest of the whole. Also, if we cut off the stem of a bean above the fifth or sixth joint, new stalks will shoot out at the joints; but it will be at the first and second, not at the fourth, nor even at the third joint, from the bottom.

* The weeping-willow is an exception to this, and there may be many more.

A bean grows by shoots; every shoot is almost the only addition to the plant; however, not entirely so, for it grows a little in all its former shoots, but that growth is proportional to the age of the shoot. For example, if there are three shoots, and a fourth beginning to grow, or growing, the third shoot grows a little while the fourth is increasing, and more than the second, and the second grows more than the first. The first shoots seem to lose their power of growth in proportion to the number of shoots beyond them; so that by the time there are five, six, or seven shoots, the first has hardly any perceptible growth: or every new shoot may be supposed to stop the growth of the first one degree; or a new shoot does not begin to grow till the last has grown almost its full length. Cut off the top shoot before it has grown its full length, and it will continue to lengthen, but not so much as if the top had been left on.

The last shoot of a plant is always the weakest part of that plant, and the last part of that shoot is the weakest part of that, and of course the weakest of the whole. This fact is best known in severe winters, or a cold beyond the natural temperature of the plant; for when the cold has been too great, we find that the last shoot either dies, or if not so severe as to kill the whole of the last shoot, it shall kill the last-formed part, so that new shoots are obliged to rise from those branches that are two years old or more.

Trees, after a certain period of their growth, which is pretty early, but more so in some than in others, generally make shorter and shorter shoots every succeeding year of their growth. But as the number of branches increases, it is more than probable that not only the number of branches of any one year's growth, but also the quantity of vegetable matter added, exceeds that of any former year. So that, although this year's shoots (taken separately) are shorter than those of last year, yet the tree has gained, not merely in an additional progression, viz. by adding the same quantity yearly; but perhaps in a geometrical progression, which is a much greater rate of increase.

Most plants have their periods of growth and periods of rest, independently of variations of seasons, such as heat and cold: for in the same degree of heat a tree may rest from growth, and then begin to grow again. Perhaps this cessation from growth arises from the formation of seed going on in the plant, or endeavouring to go on, or because it is the time it should go on in that plant; and when that period is over—the season remaining favourable respecting heat—the plant begins to grow again, producing what is called the second growth. This second growth of the branches of plants appears to be a continuation of the first; for we never find a new branch shoot out from the sides of the first growth, upon the renewal taking place.

Some plants grow equally at all times in the 24 hours; *e. g.* Asparagus, Fir, Duke of Argyle's Tea. Some plants do not grow equally at all times in the 24 hours; some growing only when it is dark; *e. g.* Beans, Peas, Lupins.

The circumstance of many vegetables shooting out branches when the trunk is cut off, would appear to arise from a certain quantity of action necessarily taking place in the plant; so that if it be destroyed, or obstructed in one part, it takes place in another. This is somewhat like St. Vitus's dance in the human subject[1].

When trees shoot out many suckers, or many and strong lateral branches from the stem, we may be sure there is a deficiency in the growth of the top, the growth of the top not being in proportion to the growing power of the tree.

When a tree sends forth its new shoots, and the leading one is allowed to grow, then the harmony of growth is preserved; but if the leading shoot is broke off, then there is an endeavour in all the lateral shoots to become leading shoots; but some one gets the start, and then the whole affair becomes settled.

Many vegetables form their flower on their extreme shoot: such can never have a leading shoot, but must be obliged to grow from a lateral shoot or branch: such can never grow tall and straight, but must grow bushy; they may grow more or less into large bushes. I believe all the annuals, without exception, form their flower on their extreme shoot. In them, the flower forming on every shoot cannot hinder a repetition of the growth, as the whole dies away in the same year.

The same observations are applicable to those whose stalk dies away every year, but which form a new stalk from the root; such therefore may be said to live by suckers; and there should be a term expressive of this, as it is their great characteristic.

Then there are those which may be said to have no fixed termination of existence, but live for years, which may include shrubs and trees. These [perennials] appear to me to be of two kinds; with an intermediate one like the former, having its flower on its extreme branch, so that it never can grow to any great height, but must become thick and bushy; the large Sumach is of this kind; every branch terminates

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1 [This is eminently characteristic of Hunter's faculty of discerning, like the Poet, similitude in things to common view most unlike. It also illustrates the never deviating aim of his unintermitting investigations of living phenomena, to gain materials for the foundation of a scientific knowledge and treatment of disease and injury.]

in a flower; but it is reasonable to suppose that it is a plant of a warm climate, for its later shoots or branches do not come to perfection; and as the winters here are too cold to allow it to live, the extreme end on which the bud is to form, dies, and the flower is prevented from forming in the summer following. The Elder is also of this kind; but as it is a more hardy plant, more of its branches flower, and some live through the winter to flower next summer, but they still terminate in a flower.

A mixed instance is that in which, in some branches, the growth shall go on in the leading shoot for one or two years, but shall be interrupted in the second or third year by its terminating in a blossom. The Horse-chestnut is of this kind, as also the Mountain Ash; but it is not until they have arrived at a certain age that they flower: until then they have the true properties of a tree. By this I mean that the whole plant continues to shoot or elongate in both trunk and branches; all of the Fir kind are probably the best instances of this.

Of Climbing Plants.—All plants are not capable of supporting themselves, and therefore are obliged to have recourse to some mode of support; they are such as grow in length beyond their proper or proportional thickness.

The climbers, the Ivy for instance, are, I believe, not numerous; but both the twiners and the clingers are an extensive tribe. We may call 'creepers,' those which pass horizontally; 'climbers,' those which ascend; 'twiners,' those that twine round a body; and 'clingers,' those that lay hold of lateral support. The first is the weakest; the second and third are next in strength, and I believe pretty equal; and the last is the strongest. I believe most form lateral shoots, although not all; the last probably the least; although they do, as we see in the vine. Those that go on horizontally have gravitation for their principle; but those that ascend on trees, walls, &c., I believe have an attractive principle; probably it is touch, as in the climbers and clingers, to which [the thing touched] they immediately bend or incline; for instance, the Ivy. The twiners seem to depend on another principle. There are some that partake of two principles, and are both climbers and clingers.

The creepers are a large class.

The twiners are a large class, and what is very curious in them, is the constant manner in which particular kinds twist round bodies. According to this regularity, they may be divided into two, viz. those that, as they ascend, always go round from left to right, and the contrary of the others. The Hop and Honeysuckle go from left to right, or with the sun; the Pea and Convolvulus go the other course. This regularity must depend on some principle, and I conceive it to be the following:

—The fibres of which they are composed grow spiral, and in the same manner they turn.

The clingers are also a large class. The Vine may be given as an instance; its tendrils move in all directions in search of a hold, and when got they cling round it, and in any direction. The Passion-flower is of this class.

The Virginia-creeper may be given as an instance of both climbing and clinging. It is curious to observe this plant clapping its tendrils to the wall; then they become broad at this part, and stick by a kind of suction, or attraction of cohesion; or they will insinuate themselves into holes or crevices. It is curious to observe its tendrils always inclining to the wall, although they may arise from the side of the stem opposite to the wall.

It would appear that weakness in anything that has powers of action within itself, produces or stimulates the parts so weak to take all advantage of collateral support. Even a bean, which, when strong, seems to depend entirely upon its own powers, yet if it grows weakly, as when not in the sun, or [from] any other cause acting to hinder strength when growing,—in such, if a stick is put into the ground close by it, it will twine around it in loose spiral turns[1].

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[1] [The following, in answer to inquiries by Hunter, is in the handwriting of the celebrated pupil of Linnæus, Daniel Charles Solander, M.D., the companion of Banks in the circumnavigatory voyage of Captain Cook:—

"Dear Sir,—I received your's, and have considered your Qs., which, as general questions, are very easily answered: but when we come to particulars, to tell how many have twining stalks, how many rooting stalks, and what number support themselves by cirrhi or tendrils, how many by shutting up their leaves at night have the appearance of sleep, which are affected by the touch, and how many have self-motion,—we shall find it very difficult to ascertain the exact quantity even of the plants that are known, both for want of observation and recollection. However, the general answer is, that all the plants in which these different motions have been observed, bear no proportion to the number of those in which we see nothing but the common mode of vegetating and growing. Supposing there are 13,000 vegetables known, I cannot recollect above 773 out of that number which have any particular motion. I have made a hasty calculation of these as follows, viz.—

Somniferous plants	448
Caule volubili	195
Caule radicans [sic, in MS.]	16
Foliis cirrhiferis	107
Affected by the touch	6
Having self-motion	1
	773

"This calculation can by no means be depended on as near the quantity that has the different motions mentioned above; there is no doubt a great number of plants that sleep at night which have not been noticed; and we shall, in all probability, by observation find many that have self-motion, &c. On the whole, the different modes

Of Motion in Vegetables.—All plants are not endowed with evident motion, many being perfectly at rest, having no actions going on in them but those of simple growth, which is the most simple state in which we can conceive life to exist.

Some, however, have motions produced in parts of them, from particular causes, as the rising or setting of the sun, &c. Others are affected by the touch, so as to be immediately put into motion. Some have diurnal motions going on regularly and uninterruptedly, but so exceedingly slow, as to be with difficulty perceived: others, again, have constant motions, at least through the day, going on so quickly as to be easily detected by the eye[1].

On what circumstances these motions immediately depend,—whether they arise from the action of structures formed for this purpose, or from a series of contiguous structures so conjoined as to produce the effect by their successive motions—we are at present ignorant. It is probable, however, that the power is analogous to the irritability of animals.

Some vegetables have their leaves closed up in the evening, as the Sensitive-plant; in most they are not in the least affected by either evening or day.

To ascertain the cause of the internal influence which produced these effects in the first, I made several experiments. As the visible difference between day and night are heat and cold, light and darkness, I made the following experiments upon these principles:—

For distinction, I shall call that action which appears to arise from the greatest quantity of vigour, *extension*; and that action which appears to arise from a loss of power, *flexion*; although many of the motions themselves, with regard to the position of parts, are not always strictly so.

I took a Sensitive-plant, and in the evening, when it was in a state of flexion, put it into a room. At five o'clock in the morning, a little while after sunrise, it was beginning to expand its leaves and erect its stalks, and continued this position till about five o'clock in the evening, when it began to close again, but before the light was materially gone.

The second day I kept the room dark till five o'clock in the afternoon (the time that the others were beginning to close), and it expanded itself and kept expanded till dark, when all its extremities began to collapse.

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of plants are very imperfectly known. We have little acquaintance with the plants of hot countries; and those of Europe have been more studied for their uses than for the advancing of natural knowledge."]

[1] [In the *Hedysarum gyrans (Desmodium*, Decandolle) there is a continual motion of the leaves by day, independently of atmospheric movements.]

The third day I kept it in the dark room all day, and it kept in the flexed state; about eight o'clock in the evening I threw a light upon one leaf from a concave mirror, by means of two candles put close together, which was continued three hours, but it had no effect.

The fourth, fifth, and sixth days it was kept in the dark room, and still continued flexed, but was beginning to decay.

This process of expansion and collapsing does not arise from an increase and decrease of heat between day and night; for in the winter, in the hothouse, where there is very little difference in the degrees of internal and external heat, and less so in the house, where a pretty regular heat is kept up, we find this plant performing the same motion.

If the stem of the *Mimosa pudica* be touched with a hot wire, the leaves above collapse.

If the top of a branch or pinnule is touched with the hot wire, the whole leaf gradually collapses, then all the leaves above, while only one or two at most collapse below.

Stimulants, such as a strong solution of common salt, did not produce a collapse, excepting when put on the joint, and this uncertain.

Ether applied to the layers of a pinnule will oblige the whole leaf to collapse, as also other leaves on the stem, both above and below: a cut into a strong stem will not produce a collapse; but if into the tender part, it will produce a collapse of all above, and commonly on the same side; but a deep cut may affect the other side. Tie a ligature round the stem or stems of a branch, it may be cut below this without affecting the petiole or pinnule above; the branch may even be cut off without a collapse. If a collapse be produced, they do not expand so freely.

It is curious the not collapsing of the leaves upon being gradually heated, so as to be burnt. It would seem that the presence of the heat hindered collapsing.

The Sensitive-plant has evidently parts fitted for motion. At the setting on of the footstalk to the stem, and the joining of the folioles to the *rachis* of the compound leaf, there is evidently a part in both different from the other parts of the same stalk, &c.[1] It is in these parts that the flexion and the extension are performed: but when the leaf performs a rotatory motion, which it will do when the plant is inverted, the whole of the footstalk appears to join in this motion, so that it is simply a twist upon the axis of the footstalk.

In the *Dionea muscipula*, or Tipitiwitchet, the whole of the lobed part

[1] [Hunt. Preps. Phys. Series, Nos. 29, 30.]

of the leaf has an equal motion through its whole length, and it appears to be nearly equal on all sides; for in its various motions the lobed part is bent towards that side where the plant bends; it performs a kind of conoid motion.

To see if the actions of plants were affected by a continuation of stimulus similar to those of animals, I made the following experiments.

As I took for granted that the analogy could go no further than as it related to the actions produced by external stimuli, my experiments were only made on such plants as exhibited actions of this kind.

As those parts of plants which are capable of the second and third kinds of motion are generally small, as leaves, tendrils, flowers, &c.[1] it is difficult to discover the mechanism upon which the motions depend: the sensitive plant is probably the best of this kind that we are as yet acquainted with. As the motion of the petioles is confined principally to one part, and that differing from the others in external appearance, which difference is its increased thickness and uniformity of surface, upon cutting the footstalk longitudinally, as also the stem on which it stands through its whole length, the following appearances may be observed[2]:—

For the purpose of making my experiments I took three sensitive plants, having several others for any comparative experiments which might be thought necessary. I first pitched upon one leaf in each plant which was capable of the greatest motion of collapsing and erection; and behind each of these leaves a board was placed, on which was marked the greatest extent of the two motions, so that the leaf was like the index or radius of an arc.

To have the greatest part of the day before me, I began my experiments at eight in the morning, while the leaves were in full expansion, and I continued them till four in the afternoon, as longer than this would not have been just, for they begin to collapse of themselves between five and six o'clock.

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[1] [The stamens of certain plants offer striking examples: those of *Saxifraga* approach in regular succession the pistil, and as soon as each has shed its pollen over it, it retires and gives place to another. The stamens of the barberry show more active movements. In the tiger-lily the pistil pends first to one stamen and then to another.]

[2] [A blank in the manuscript here occurs, which leaves us ignorant as to the result of Hunter's examination of the structure of the irritable intumescence at the base of the leaf-stalks and stalklets of the Mimosa. With his usual sagacity, however, he rightly refers the motive power to this part, and it has since been the subject of much diligent and minute investigation.]

Comparative Trials of the Action and Relaxation of Three Sensitive Plants.

Exps.	The time.	The point they fell to.	The times they took to rise in.			The point to which they rose.
			No. 1. min.	No. 2. min.	No. 3. min.	
1.	8 o'clock A.M.	To the lowest point, and became stationary.	51	24	32	The 1st and 3rd rose to the highest point, the 2nd not so high, and then became stationary.
2.	9½ A.M.	To the lowest point, but the second lower down.	77	18	38	The third rose to the highest point, the 2nd and 1st not so high, and then became stationary.
3.	11 A.M.	The second & third lower than lowest point.	40	30	60	All three rose to within a little of the highest point, and there became stationary.
4.	12 Noon.	Below lowest point.	30	30	35	All three within a little of the highest point.
5.	40 min. P.M.	Below lowest point.	60	65	30	The 2nd and 3rd to highest point, the 1st not so high.
	2 P.M.	1st only below lowest point.	45	45	45	Ditto.
	3 P.M.	Ditto.	45	45	45	3rd to highest point, the 1st and 2nd not so high.
	3½ P.M.	Below lowest point.	15	15	15	1st and 2nd to highest point, 3rd not so high.

From these experiments we may draw the following conclusions:—

That there is no fixed time for the leaves of any of the plants to move through its course.

That they are less affected as they become accustomed to the stimulus, but the power of collapsing is increased (although not in the same degree), so that they do not move through the same arc.

That they require a stronger or quicker stimulus to produce motion after being some time accustomed to it, which was evidently seen in comparing these with others which had not been stimulated.

It may also be observed that when these plants collapse in the evening they have nearly the same quantity of flexion as when roughly touched at noon; but if touched after they have collapsed from the effect of the evening, they become much more bent than by the same touch at noon. This would seem to arise from a disposition to collapse in the evening, and a power of increasing that disposition and action when stimulated.

Their collapsing more in the day, and erecting themselves less after a repetition of such actions, may assist in explaining the principle on which this depends.

Of Relaxation in Vegetables.—There is an action in plants which appears to be the contrary of expansion; it may be considered as a relaxation, or an action of those parts antagonizing the others which acted through the day, or at other periods, and takes place at the time these other parts cease to act.

This action has hitherto been considered as analogous to sleep in animals, whereas sleep is a total loss of the sensitive principle and all the actions dependent on volition for the time, and therefore can only take place in animals endowed with sensation*. It is rather a defect in the animal than an action or the exertion of a principle.

This action of relaxation is seen in the sensitive plant when the folioles close upwards and are kept bent by the power of action in the flexors, till light and some other of its attendants affect it, when the extensors begin to act, and this action of the flexors ceases. The foot-stalk dropping down favours the idea of simple relaxation; but this only arises from the position of the plant, for if turned upside down it still bends against its own gravity[1].

The one action is produced by the stimulus of light, the other by that of darkness; for if the sensitive plant is kept in a dark room it will keep bent, and perhaps as long as it lives; and if one part of the plant is kept in the dark and the other in the light, that in the dark will be bent, and continue so, while that in the light will expand itself.

Light and darkness become stimuli to the same plant, and have much more influence over vegetables than could at first be imagined. Many plants only grow through the day, others only grow after it is dark.

Sympathy in Vegetables.

Sympathy is the action of one part in consequence of an application being made to another part, or action in another part.

This power of action is extended to few plants, and even in these appears to have little variation. It is evident in the sensitive plant; for if one of the little leaves be wounded at its termination it will collapse immediately, as also its fellow on the other side. This action runs through the whole of the rachis of the compound leaves, the leaves bending regularly in pairs.

If it is a middle foliole that is wounded the same thing takes place; they all collapse towards the footstalk, but seldom towards the extreme

* The polypus does not sleep.

[1] [The powers which produce the depression and elevation of the leaf-stalk operate in a manner precisely the reverse of the flexor and extensor muscles in animals, pushing the moving part from, instead of pulling it towards, the fixed point. The distension and collapse of cells through movement of the sap, appear to be the chief physical changes accompanying these movements.]

end of the leaf, and in a little time the rachis is inflected and the whole leaf drops at the trunk. It may be remarked that a small flexion takes place towards the tip; but this principally arises from a disposition in the folioles, for a middle one cannot collapse without pressing or folding a little on the one next to it towards the end of the leaf which stimulates it and makes it collapse.

It is evident in the tendril of the vine, for these tendrils generally divide into two, near their ends: these two going out from the principal trunk in different directions, if one lays hold of any body and twines round it, the other immediately alters its direction and gradually approaches the same body till it comes in contact with it, and then bends round it and encircles it. This motion, however, is very slowly performed.

Sympathy in plants is very slow in producing its actions; the succession of stimuli in them being slow, the consequent actions must also move slowly along.

Plants have but one mode of sympathy, which arises from stimulus. Animals with no brain or nerves have but one also. Those, however, endowed with sensation have three: they have one mode from stimulus, one from sensation, and one compounded of both[1].

Sympathy in animals, arising from stimulus only, is slow, as in plants; but sympathy from sensation is often very quick.

In the Vine, if the stem rises perpendicularly, the footstalk generally comes out at an acute angle with the stem above; but if the stem hangs, as it often does, then the petiole makes an obtuse angle with the same part of the stem. This action is performed at the setting on of the petioles. But in this last position of the stem the footstalk is obliged to make a twist of half a circle to bring the upper side again uppermost; and this twist is principally performed at the root of the petiole, but it in some degree runs through the whole.

The flexion and extension, with the conoid motion, must be performed by longitudinal contracting powers, but the rotatory motion must be performed by oblique.

With the idea that it was possible that the contracting power of vegetables might be muscular, and therefore the same species of matter as animal matter,—especially, too, as they yielded the same matter when analysed, although not in the same proportions,—I made the following experiments:—

I cut off from several leaves of the Sensitive-plant the active part of

[1] [Animals manifesting only the 'reflex phenomena' of the nervous system, are here contrasted with those exhibiting, also, 'sensational phenomena' associated with the possession of a brain.]

the petioles, and also of the folioles, and put them into a phial of water, No. 1.

I took as much in quantity of the inactive part of the petioles and put them into another phial with the same quantity of water, No. 2, and sunk them both into the tan in a hothouse. When they had stood thirty-six hours, I smelt them both, and found that phial No. 1 had a pretty strong sickish or faintish smell, but that of the other was hardly perceivable. When they had stood forty-eight hours, I found the smell of the first increased, but not that of the second. I took some of the water of the first, and put to it the syrup of violets, and it turned it of a very fine green; No. 2 had no effect upon the syrup. It did not produce the same effects again, and I continued them in it for more than three weeks, upon the very same parts, and at last they both produced an acid.

The St. John's Wort opens its flower when it is dark, never when it is light; but they never close again when it is light, as do the Convolvulus [*Ipomœa bona-nox* Linn.], Evening Primrose [*Œnothera*, several species], &c.; indeed, I believe its flower only lasts one night and one day.

I have seen Honeysuckles which flowered in the night, two of them before twelve o'clock at night. A Holyhock, whose flower was protruding in the morning, opened in the forenoon.

Of the Action of Light.—It was thought, from common observation, that light was the immediate cause of the green colour of vegetables; but upon a further investigation of the subject, it appears to be only the remote cause. That it is not an immediate cause in all cases is plain, from vegetables of the same species not all being green; nor green in all parts of the same vegetable, as the Variegated Holly, Aloe, &c. Besides, many vegetables are green through and through their whole substance, as the &c.; [some mosses, lichens, confervæ] and many vegetables that are green on their outside, viz. in their cutis and in their new layer of wood, especially when but newly formed, are also green on the inner surface of the canal of the pith, as in the young shoots of the Elder. From all which it would appear that light is not the immediate cause of the green colour, but a remote cause, viz. the cause of a certain degree of health or proper action, which produces the green colour; and that those plants or parts which are not green, when exposed to the light, are not capable of taking on this necessary mode of action, although under the influence of light. In other words, the light is capable of stimulating most plants to such action as produces a green colour in certain parts of the plant, no matter whether immediately, or not immediately, under the influence of light.

The leaves of most plants are green, but not of all. In those that are naturally green, we find that in proportion to the health of the plant the green is darker; and when not healthy, it is more of the yellow cast. Those that are naturally yellow do not change: yellow is more or less the colour that green vegetables take on in the act of dying. Therefore when plants are not of so dark a green as common, they have but few or little powers of life. A dark green in any plant shows great vigour of life, and the growth is luxuriant.

Of the Leaves.—Some plants throw out their leaves much earlier than others.

Query. Are those plants of colder climates, because they can vegetate with less heat than those of warmer climates? and, conversely, of vegetables of warmer climates, as they require more heat, are they, in some degree, kept back in putting forth their leaves? If so, then we might judge of the warmth originally suitable to a vegetable by the comparative times of their throwing out their leaves and flowers.

We sometimes find trees throwing out leaves, and even blossoms, about the beginning of October: such I have observed have dropped their leaves very early in the autumn, so that they had gone through their suspension of action a sufficient length of time to take on a new action. But such late growths are commonly, if not always, weaker than those in due season; the leaves are paler, commonly with a mixture of yellow, which denotes weakness.

I had a Lime-tree that threw off its leaves in August; I thought it was dead, but it threw out a second set of leaves in the latter end of September; but they were pale, therefore not healthy or vigorous. A Horse-chestnut tree at the King's Head door, Brompton, had one of its branches which lost its leaves very early in the season, and by the latter end of September it had shot out fresh leaves and a full-grown flower: the leaves were paler than those in due season.

Leaves have considerable motion when the wind blows. Is this in some degree to take off the force of the wind upon the whole tree?

Some trees, as the Birch, Poplar, have much smaller branches than others, the stem being the principal part; such also have small leaves; of course those that have large branches having larger leaves.

Of the Casting of the Leaves of Vegetables.

Every vegetable is deciduous, but differs in regard to times, and probably may be divided into the following:—

The first is what may be called annual, being similar to those plants which die the same year or the same season, or rather when finished growing, as in all the plants commonly called deciduous; but to keep to the true analogy, they should be called , as it is similar to those whose stalks only live the same summer, but the roots live, and shoot out new stalks; however, it is never the last or former year's shoots that throw out leaves, it is a new shoot.

The second is what may be called , or the second season of its age, or when it has finished the second growth. This would be similar to the Raspberry; for the Raspberry does not die in the same season of growth, as many vegetables do, but in the second season, as do the leaves of the Scotch and Weymouth Pines, Laurel, &c.

The third may be called , or the third season of its age, or when it has finished its third shoot, as in the

There may be a fourth, a fifth, a sixth difference in regard to the times of casting the leaves; the last of which seems to be the case with the Spruce. Every winter exemplifies the first class, and in all of the Pine-kind this fact is easily known; but in most others of the second, third, &c. [difference as to times] the facts can only be known by a succession of observations.

The casting of the leaves of plants is most probably similar to sloughing or exfoliation in animals. It is at least an operation of the plant, producing a separation of the leaf; and the only thing that proves it is, that the leaf will not fall off if the plant, and of course the leaf, be dead; but if the leaf dies, although long before its destined time, it withers, is separated, and falls off; but if both the plant and leaves die at the same time, viz. before the separation has taken place, then the leaf will not fall off, even when dried.

These facts show gardeners whether a new transplanted plant is dead or alive. If the leaves fall off by passing the hand over them, then they are sure the plant is alive; but if they do not fall off of themselves, nor can be separated by passing the hand over them, then it is most probable that the plant is dead.

Of the Change of the Colour of Leaves and Stalks of Vegetables from the Green to the Yellow when dying.—This change is an operation of the living powers of the plant, and not simply death taking place. It is extremely gradual when the part is as it were allowed to die a natural death; but either a great drought or a few frosty evenings will hasten on the decline, and they die sooner or faster. That it is an operation of the plant arising from debility or the stimulus of death, is, I think, evident; for if a plant in full vigour, in which it is at the greenest, be killed immediately, by putting it into boiling water or by electricity, it retains its green colour, and will die green, and even dry that colour: whence we may suppose that the strongest plants, or those with the greatest powers of action of any one species, will be of the deepest green; and I believe that this is shown every day by experience.

They not only retain their colour after death when killed suddenly, but they retain other properties; for if dried in that state and wetted again, they come back again much more nearly to the fresh plant than those which die gradually or naturally*.

Of the Natural Decay of Parts of Vegetables.

Vegetables have many of their first-formed parts die while they are forming new parts. Thus, many trees prune themselves, as probably all of the Fir-tribe; but this is more or less according to circumstances. If a tree stands alone, so as to have a thorough air and light surrounding its lower branches, there will not be that disproportion between the branches and the leading shoot, as if the branches were otherwise circumstanced, and in proportion as the branches are allowed to grow, the leading shoot is more stinted in its growth. This is the reason why in woods, where the trees are growing thick, they run up tall and straight, and have few or no branches below; for the lower they are they become sooner under the influence of shade and confined air, while the upper branches are not yet so long as to meet each other, so as to exclude air and light in a considerable degree.

Of the Effect of different Winters on Vegetables.—It appears from observation that a long hard winter does more harm to vegetation than a much severer season of a shorter duration.

The January of 1775, when the thermometer was about 10°, 15°, or 20°, did less harm than the spring of 1780, which was late, although the thermometer was seldom lower than 20°. However, it may be remarked that in the winter of 1775 there was a good deal of snow, while in the winter of 1780 there was none.

Buds.

A plant that continues its shoot for two or more years, has always terminated the preceding year in a bud.

Buds are the *ovum* or the *embryo* of a shoot or flower.

In the bud is contained the whole of the following year's shoot, and when the shoot is fully blown or extended, then it forms another bud or buds. It may be a continued bud, as in the ; or a continued bud with lateral buds surrounding it, as in the Fir or Pine; or the continued bud may not be formed, but lateral buds only, as in the Lilac.

* The mode of making hay might be improved by this principle[1].

[1] [It is that on which the edible, soft and succulent vegetables are preserved by the process invented by M. Masson, for which a 'Council Medal' was awarded at the "Exhibition of the Industry of All Nations" in 1851. See "Reports of the Juries," 8vo, vol. i. p. 156.]

When a bud contains a flower, it also contains everything relative to it.

A bud and a leaf are generally, if not always, formed together, whether on the side or the termination of a shoot.

Buds in most trees, the Scotch Fir and Weymouth Pine excepted, grow on the sides of the growing stalk, forming as the stalk forms, each bud having a leaf annexed to it. A bud never forms on the side of a growing stalk, or on any part of a stalk after it is formed; but as the external surface of a tree is growing every year, or rather as there is a new layer formed every year, there are places formed in the bark which answer the purpose of a bud, when such place is stimulated to action by cutting off the intelligence with the parts above, which obliges it to supply what appears to it to be wanting; but all trees have not this.

It is not clear to me but that these parts were originally buds, which did not sprout, and by that means became flatter and flatter, but still retained the disposition of a bud when called upon. All buds are not intended for branches, only for leading stalks, in case the stalk should be broken, as in the Bean.

The lateral buds in many trees appear to be so much a termination of the shoot, that the leading bud is obliged to strike off obliquely, which is more or less the case when the buds form alternately. It is remarkably so in the Lime-tree, making the whole shoot after it is formed take a zigzag course. But when the buds arise or are formed in pairs or in clusters, then the leading shoot goes on straight, being equally influenced on each side or all round. Most shoots go on in a straight line with the stem, whether of a branch or main trunk; but the Virginian Creeper would seem to be always growing backwards, having its last-grown part bent backwards on itself for two inches, and as it grows, it is in the same proportion unbending itself.

Probably every tree has in its nature an annual cessation in growth. This is perhaps better illustrated in the Lilac than most others. This plant terminates its summer growth in two buds, exactly similar to those on the sides at the attachment of the leaves; and the bud has no disposition to grow till it has lain dormant some time. Query: What is the reason of all this? Is it because the last year's bud has fully expended itself, therefore can shoot no further, and must form a fresh bud to go on with next year?

The bearing part of every vegetable is either one year old or of the same year, so that those parts that are older are only employed in the support of the new in every mode of support.

Most plants that have branches, but not all, form in each shoot the buds of the branches of that shoot; which either shoot out the same year, or wait till the year following; or both may happen in the same plant, according to the earliness of the shoot, as in the Privet, Cherry, &c. Others, as the Holly, have all their buds growing into branches in the same year. Others, again, never form lateral buds for branches, but the shoot terminates in a cluster of buds, the outside ones intended for the branches, the middle for the stem; such are the Scotch Fir and Weymouth Pine, which confine their branches to clusters.

Some vegetables, as the common bean, would appear to have particular places for the formation of branches, or rather of stems, when the original stem is destroyed by any accident, and which places are to be considered as so many buds.

Cut off a stalk below the first joints or leaves, then a new stalk will grow out from the bean in the ground, which would not have grown if the first stalk had not been destroyed.

Cut off that new stalk below all the joints, and a new stalk or stalks will still shoot out from the same bean.

Cut off the stalk above the first shoot, joint, or leaf, then a new stalk will not grow from the seed or bean, as in the former ones, but from the joint, shoot, or leaf below.

Cut off the stalk above the second joint, leaf, or shoot, and then two stalks will shoot out; one from the first joint, and one from the second.

Cut off the top of the stalk above the fifth or sixth shoot, and the new stalks will shoot from the first and second, &c. joints, but not from the last joints, or those nearest to the top.

Cut off the young shoot, and a third will grow out from the root of that, so that these joints are similar to roots or seeds.

Of Generation and Germination in Vegetables.—The male parts in vegetables for the most part far exceed in number those of the female. I am not now considering the seeds as a female part, they being only a production of the female.

The stamens, which are the spermatic vessel and testis, or true male parts, are in much greater number than the styles or female parts; and the number of particles of the pollen, which are the production of the male parts, far exceeds the number of seeds in the female.

The produce or effects of the female parts are pretty well determined with respect to number, viz. the number of seeds; but the produce of the male, although pretty well determined, yet its effects are not; for they do not make a part, but only are to affect the female part, and that affection is in a good measure a matter of chance. It is like shooting at a bird with a great many shots, when one would kill with certainty if properly applied.

As vegetables are every year, or are constantly, supplied with an addition of vegetable matter everywhere on the outside, they must have their parts respecting external influence renewed every year, such as the parts of generation; therefore they may be said to be always young, because these new-formed parts are young, and it is those young parts that perform the natural actions of the plant.

The Hazel-tree sends out its male parts in August and September on the same summer shoot, by the side of a bud. Is the male tree strongest; *e. g.* in a Palm?

To produce seed is the ultimate power in vegetation. In vegetables there are several stages of perfection. The first is the flower, at which stage the vegetable may proceed no further; the second is the fruit, which may be produced, but not with perfect seed; and the third is where the whole is perfected.

When a seed is put into the ground the root commonly grows downward from that seed, although the point from which the root grows is placed upward. *Vice versâ* with regard to the stem.

The first growth in a seed is the root, and then the stem. Cut off the root, a new root sprouts out; but the growth of the stem is stationary till the new root is fit to carry nourishment to the plant.

Monsters in Vegetables.—In vegetables we have monsters; that is, a deviation from the common principles in some of the productions, either in form, flower, seed, or colour; and this it is which has produced the varieties in species. It arises more from cultivation than any other influence; and the cause of varieties, viz. cultivation, becomes also the cause of their being preserved and propagated. Their propagation is, in many, perfectly artificial, viz. by budding or engrafting; but, when left to the natural mode of continuance, they either go back to the original again; or, at least, it is not certain what will be the produce; a new monster may arise. All our finer fruits are instances of this kind. In some vegetables, when a monster arises, it never dwindles gradually back into the original stock; but keeps the same, excepting another monster arises, which may be that of the original stock from whence it came, or any other. Beans, Peas, &c. are changing every day.

Vegetables are much more in our power to manage than animals. Thus a plant can be made a dwarf, it can be made to shoot strong, it can be made to vary, it can be made to bear.

[*Loose Notes.*]

Qu. Has any one of the juices of a vegetable the power of converting either animal, vegetable, or even earth, to living vegetable matter, similar to that [power in the gastric juice] of an animal?

Mem. To cut off the flowers of the Leek, to see if it will shoot out more young Leeks than common on that account.

A TREATISE ON ANIMALS,

IN THREE BOOKS[1].

BOOK I.

OF THE STRUCTURE AND COMPOSITION OF ANIMAL BODIES.

CONTENTS.

Book I. Chap. I.—INTRODUCTION.

PEOPLE who stand up for antiquity, and want to carry all knowledge as far back as the first teachers, which knowledge really does not belong to them, instead of raising their character rather injure it. They are obliged to strain points, wrest meanings, and collect different passages of such authors which are most to their purpose; and, after all, they make it but very imperfect. Now, if the ancients really understood any piece of knowledge that we look upon as modern, and if their account be really so dark and imperfect that there is no understanding them without previously understanding the subject, it shows that they were much more stupid in not transmitting to us intelligibly what they knew, than if they had not understood the subject at all. This, however, is not the ancient way of writing; for, whatever they understood themselves, they have recorded it to us in a plain perspicuous manner, which is much to their honour.

Let us consider how we are to judge whether a branch of knowledge be ancient or modern. First, let a man that knows nothing of the

[1] [This is, apparently, the outline sketch of the anatomical part of the great work on Comparative Anatomy and Physiology, the materials for which form the Hunterian Museum in the Royal College of Surgeons of England.]

subject be made perfect master of the ancient notion; and then let us see whether or no his notions are exactly the same with the present: if they are, then the ancients understood it; if they are not, then we may conclude that they did not. Secondly, let us examine what happened when this notion made its first appearance. If it seemed to be new, then we may say that it was so; for we must suppose that the ancient notion was known at that time: if it met with opposition, then it was certainly new; for the opposite must be in favour of the ancients: and, if it even met with a friend, it was a sign that it was new.

A man with a sufficient fund of knowledge, and a close application to one art or science, will make great improvements in it though his talents may not be the best; or, in other words, though he be not a great genius.

There are three ways of obtaining a knowledge of physics, which differ in an equal proportion from one another. The first and least useful, is by reading; which, indeed, ought not to go first, but to follow the second or third. However, it is of more use, as we shall see, to the second; for it helps to explain what perhaps we did not understand. What makes this [reading] of least use, is that it leaves us to conceive everything, none of our other senses being struck thereby, though it comes nearest to what we learn by the sense of hearing.

The second way is twofold, 'demonstration' and 'description[1].' The first of these must always attend the last, but the last may not attend the first, though it always ought to be joined with it; so that the second way includes two methods of acquiring knowledge in one sense, and but one in another. It will be greatly assisted by reading, and, without reading, will be far preferable to reading only. But demonstration ought to be the first step; for description without demonstration is little better than mere reading.

The third means of acquiring knowledge is by much the best: it is no more than the former two taken together by oneself; that is, for a person to be his own operator and instructor. This is not so easily compassed; for, besides the faculty of comprehension, it requires dexterity of hand, and also some preceding knowledge of the subject. So that demonstration is what we should begin with, then manual operation, and lastly reading.

Demonstration shows us matter and its properties. Manual operations fix these more firmly in our mind, as we are always more attentive to what we do ourselves than we are to what others do. After

[1] [Here oral description is meant; such as is given by the demonstrator of anatomy to the students in the dissecting room.]

that, reading (which is like going through the operations a second time) will be very useful; and, as we get by the former a general knowledge, we are now able to understand, by reading, what we did not know before, nor could have known without that previous knowledge.

Progress of the Study of Anatomy.

Anatomy, or the knowledge of the structure of an animal body, may be said to be, first, [acquired] for the good of the animal itself; secondly, for a variety of purposes which have a relation to that structure, such as sculpture, painting, &c.

An animal body is to be considered in two ways; one in a mechanical point of view, the other as regards the internal economy. The first mentioned is the first to be considered. In the examination of the parts of the animal structure, the best method is to begin with the most simple or the least connected, and to proceed in that order; for, however an animal body may seem to be compounded, all its particular parts having a dependence upon one another; yet in an anatomical sense they are more or less distinct, so as to admit of distinct examination. This connexion or interdependence is not in an equal degree, some parts being immediately connected with a greater variety of other parts than others are. The order or degree of connexion is progressive, and will not admit of being reversed; for, although the second in that degree has connexion with the first, and cannot be understood without also understanding that connexion, yet the first may be understood without the second; and so on. Therefore, the parts that have the least degree of connexion, should be first considered; because, when perfectly understood, those which have immediate connexion with them will be more easily understood. I am not speaking of their constituent parts, but of the whole part as formed; and of the way of examining each part as it is compounded.

The bones, in a mechanical view, appear to be the first that are to be considered. We can study their shape, connexions, number, uses, &c., without considering any other part of the body. When they are well understood, it will be a great step towards studying the parts that have an immediate connexion with them.

The next thing is their connexion with the cartilages and ligaments, forming the first step in the composition: these, when understood, will give us the motions of the bones one on another. But the ligaments and cartilages have but little dependence on each other. The size, shape, number, connexions, and motions of the bones having been considered, we shall find that they are for the support, shape, and motion of parts, and of the whole body.

The next thing to be considered is the power or powers of motion. The muscles cannot be considered by themselves, but in their dependence upon the bones and tendons; without which we cannot bring out all their uses. In their investigation, like the bones, they should be deprived of everything but what concerns them immediately; therefore, fat, cellular membrane, vessels, nerves, glands, &c. must be removed.

The viscera are the next in order; but as the bones, muscles, blood-vessels, and nerves are common to every part of the body, and the viscera, sense organs, &c. are particular parts, it is usual to proceed with the universal or common, and afterwards with the particular or viscera.

The blood-vessels form a step beyond the mere mechanical parts; but, considering the parts only so far as mechanism is concerned, they are next in the order of progression. For the knowledge of them depends on the knowledge of the bones, ligaments, cartilages, muscles, and tendons; therefore, in dissecting them, they should be left in connexion with these, but be deprived of everything else.

The nerves come next. They are a good deal like the vessels in their dependencies; yet we choose to make them last, for these reasons: they are less understood, are more complicated, more numerous, and in general smaller.

This appears to be the most reasonable way to proceed from the more simple to the more complex parts: for, suppose we were to invert the order and begin with the nerves, we should then begin with the most complex parts, before we knew what dissection was [or had acquired the art], and we should meet, in the attempt, with several parts of which we knew nothing, such as muscles, viscera, ligaments, bones, &c.

Fat is only a luxurious accidental part; therefore does not come within the compass of dissection.

The cellular membrane we have not taken notice of; for it is what we destroy in cleaning the other parts. The best way of understanding it is by common dissection, its use being no more than a connecting medium to all the parts of a body, and dissecting, in general, is no more than destroying this medium.

Chap. II.—Of the Skeleton in general.

A Skeleton is—

A passive substance:
Sustaining or giving support:
Giving general figure to the parts or to the whole:
Determining the places or motion of parts:

And is composed of :—

Animal substance entirely: or
Animal substance and calcareous earth: or
Calcareous earth entirely.

When of animal substance entirely, it may be—

Membranous, as in
Many parts of young animals; some parts of the skeleton of some fishes:

Gelatinous, as in
Soft-shelled sea animals [Tunicata]:

Cartilaginous, as in
Some fishes:
Many parts of the more perfect animals:

Or horny, as in
Flying insects.

The hardest or firmest parts of an animal, whose use in the machine is to give support and form to the whole, and attachment to the moving powers, may be called the 'skeleton:' or if only to a part, then it is the skeleton of that part. Some consist of only one piece[1], others are made up of several pieces, having motion on each other, which at the same time directs and determines the places for motion.

A skeleton respecting the internal economy of the animal is of no use, having no action within itself so as to influence others; it is passive, as a wheel in a machine, and must be acted upon. However, its use is not so essential as that of a wheel; for wheels make a part of the internal economy of the machine. But wheels neither give support nor shape, which are two very essential uses of the skeleton.

Skeletons are composed of different kinds of substances suited to the necessity; some being extremely hard, others soft, yet of sufficient firmness to give support, and afford fixed points for muscular attachments. These substances may be membrane, cartilage, horn, and bone. The first three are animal substances, the last is a kind of mixture of animal matter and earth. These different substances are not entirely peculiar to particular classes of animals; some having two kinds, others three, and probably there may be some which have all the four. We find, too, that some animals may have one kind at one period of life, while they have another kind at another period. Some skeletons contain the whole animal, as in the oyster; others are different in

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[1] [Hunt. Preps. Phys. Series, Nos. 225, 226.]

this respect, in different parts of the body [as in the tortoise]. We may observe that, upon the whole, when the skeleton contains the whole or a part of the animal, it consists of fewer parts, with the least motion on each other. Of this shell-fish are the strongest instance, and next the lobster, turtle, tortoise, &c. And even in the quadruped, bird, &c., where the bones are in great numbers, having motion on each other, yet we find the skull to accord with the above-stated principle. The cuttle-fish [*Sepia*] might be cited as an exception to this, for it has only one bone for its skeleton, which is not on the outside, and in some kinds [*Loligo*] the internal skeleton is a horny substance.

I shall begin my history of the different kinds of skeleton with the most simple in regard to use, which may be as simple in regard to substance and construction. I conceive that where the skeleton has the least rigidity, it is least complicated in its uses; and this idea is verified in those animals where the skeleton is found to be of most varied use. For in those at the age where this part of the animal can be of little use, the most rigid skeleton does not exist; but only the soft, or that which I conceive to be of least use: and as the actions of the animal increase, rigidity becomes more and more requisite or useful; and the soft is changed to the rigid, as will be observed when on the skeleton of each class of animals. The membranous skeleton must have the fewest parts; and we find that the most inferior animals have only this kind.

The membranous skeleton is the first, and appears to be more of a tendinous than membranous nature: it is to be considered rather as a medium for muscular union, so as to give fixed points of action to distinct muscles in the flexible animals of the lowest order; a worm may be given as an illustration. Every ring in this animal may be considered as a bone, or fixed point, from which muscles pass to the other ring. The same substance is carried to different parts in higher animals, so as to supersede bone, where it can answer the same purpose; and either where no harder substance is wanted, or would be hurtful; thus tendons of muscles and ligaments of bone are to be considered as a part of the skeleton; they certainly make part of the skeleton of the animal*. In the head of the infant, as at a period when the contents are in no danger of being injured, the skeleton is only a membrane, the function being simply that of a containing part: its becoming bone afterwards is to

* In my history of muscles, in which I treated on tendons, I considered them more as a part of the skeleton than muscles[1].

[1] [Hunter here refers to his "Croonian Lectures on Muscular Motion." See my edition of the 'Animal Economy,' 8vo. 1837, p. 229.]

answer the purpose of a defence from external violence to the contained parts.

As the membranous skeleton is not stretchable, or has a sufficient firmness in texture not to yield beyond a necessary extent to the natural actions of the animal, and as, in such, the sections of motion are short, a pretty regular form is preserved; for in every natural action there is such a relationship depending upon it, that no distortion of parts takes place, and only external violence deranges the form. A worm is just as regularly a formed animal as any other, although it varies more than those whose forms are more determined by [the harder nature of] the skeleton.

The cartilaginous skeleton differs from the former in the nature of its substance, as in the consistence whereby it retains its form; but there are considerable differences in the degree of consistence, and of course in the power of retaining form. This substance is introduced in various ways, but seldom alone, as we find in the membranous skeleton; in some animals there is more of it, and in some less, when the skeleton approaches nearer to the membranous. Cartilage is used as an external covering, like a shell, as in those [*Salpa*, *Ascidia*] which I have called the 'soft-shelled animals[1].'

Cartilage is used in the body of some animals as a fixed point for the muscles to act from. And as it is not so yielding as the membranous skeleton, it is composed of parts which are united to each other, admitting of motion in those parts, and determining with more exactness the places of motion; although not perfectly, as it is elastic, yielding and recovering without the aid of antagonizing muscles. These unions mostly consist of membranes filling up the space between each cartilage; although in some the membrane makes a capsule.

This mode of introduction of cartilage is principally in fishes; and in some parts of other animals, such as the cartilages of the ribs in man. It gives more stability to the shape than membrane could, and admits of more variety of shape in animals.

Cartilage.—This is semitransparent; of various consistence according to its use; and is commonly of a determined shape or outline, seldom losing itself insensibly in the surrounding parts. Cartilages are of two kinds respecting the power of being changed for bone; one where it is forming the skeleton of many animals only before birth; the other where

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[1] [They answer to the *Mollusca tunicata* of Lamarck and Cuvier. The external skeleton, shown in the Hunt. Prep. Phys. Series, No. 76, is a dense gelatinous membrane, containing 'cellulose:' not true cartilage, but resembling it in physical properties.]

it is not, becoming the skeleton of some animals throughout life[1],—that of both kinds is a very uniform mass, breaking equally in every direction. The one which is changed for bone is vascular, and when going to be changed becomes more so, these vessels having now more to do[2].

The horny skeleton is truly animal, and is placed principally on the outside of the animal, by which means it is kept dry, which renders it stronger under the same quantity of matter. In the spade-tailed cuttle [*Loligo*] there is a horny or tortoiseshell blade that runs through the whole back[3]; besides which there is a cartilage on the anterior end of the back. In the common horny skeleton the muscles are placed on the inside, by which means it becomes a compound part of the animal, serving equally as skin and skeleton, and often other purposes. It is common but not peculiar to the insect: it constitutes the scales [rings] or external covering of every flying insect, to which the muscles are attached; besides which it sends inward horny processes for the further attachment of muscles; just as bones send out processes for the same purpose. I believe in the insect this substance is almost the sole, having very little of the ligamentous, and, I believe, none of the cartilaginous [substance combined with it]. We have no generic term for this substance[4]. I believe it is fibrous in all; growing from an end like hair, or from the edge like scales, according to its form. But when it acts simply as a cuticle, I believe it grows from a centre, or all round the edge, as in the shell[5] of the tortoise or turtle.

The bony skeleton belongs commonly to the higher orders of animals; although it is introduced into some of the lower, where firmness, strength and determinate motion, with great variety, are wanted. As it is internal, and of course always kept moist, it is a fitter substance for those purposes than horn; for horn, when moist, is elastic and yielding, and therefore when used is external. Bone is not the original skeleton in any animal, but only of the adult; for in the first formation of any animal, which afterwards is to have bone, the skeleton is either membrane or cartilage, which is changed *for* bone, but not *into* bone.

The gradations of this change are beautiful. When the animal has no locomotion, nothing to support, no action of parts but such as immediately concern life, we find no bone. But as the young animal advances towards that period in which it is to take a scope of bodily action

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1 [Hunt. Preps. Phys. Series, Nos. 78, 230—237.]

2 [Ib. Nos. 133—162. The above is an outline sketch of a histological chapter on cartilage, which appears not to have been written.]

3 [Ib. No. 77.]

4 [It is now called 'chitine,' having a different composition from horn.]

5 [This is true 'horn.']

beyond its own internal economy, when one part is to act upon and to sustain another, then rigidity becomes requisite, and bone begins to be formed in preparation for this period. This is similar to what goes on in every other part which is to come into action after birth, with a new mode of the continuance of life. Thus the lungs, stomach, intestines, with every thing relative to them, the brain, nerves, senses, and extremities are forming, from an early period, so far as to be useful when the animal comes, as it is calculated, into the world. The substitutes for bone at those early periods are cartilage and membrane, but cartilage chiefly. And this varies in consistence according to the age. It is, at first, almost a jelly, and becomes firmer and firmer as the fœtus may move upon itself. But as it is not wholly changed for bone at birth, what cartilage remains is become, by this time, fit to act as bone. Where the least power of resistance is wanted, where no action can take place, there we have only membrane; and this membrane is only to contain, and to allow itself to be changed for bone; such as what covers the brain; for, while in the state of a fœtus, the brain requires only to be covered, similar to the abdominal viscera; but, by the time of birth, it wants something more.

I shall here observe that the cartilage of those animals where there is bone, is of two kinds: the one that is changed for bone is a uniform mass, but that which does not is fibrous, and is placed on the ends of bones, forming the cavity of the joint; and as it is for the purpose of the motion of the joint, it remains a cartilage through the life of the animal. The cartilage that is changed for bone is of two kinds respecting the time of change: one is where the change is complete when the animal has arrived at its full growth, forming what are commonly called the 'bones.' The other is where the period of change is uncertain, seldom until considerably after that of full growth. Such commonly retain their original name of cartilage, and when they do become bone, are said to be ossified: such are the cartilages of the larynx, and of the ribs or sternum. The earth in bones is not to be considered as a part of the animal; it is like the fat; for it can be diminished or increased by simple absorption or deposition. It is a secreted substance, and, as it were, thrown out of the machine simply for a mechanical purpose. It is not required to be of the nature of the machine, for it can be made up of parts, *e. g.* madder, that are not altered by the stomachic process.

The stone in the bladder, which cannot be considered as part of the animal, is coloured in the same manner as bone; the urine being the carrier of the madder out of the blood.

As those cells that contain oil are called 'adipose membrane,' *cellulæ adiposæ*, I think the animal parts of the bone should be called 'calcose membrane,' *cellulæ terrestres seu calcareæ*.

Young bone may always be said to grow, even the part that seems to be already formed; for at first it is growing longer, thicker and denser; so that there is always new matter added until it is at its full growth. But in the full-grown state, it would appear from the circumstance of reddening a whole bone by feeding the animal with madder, that a bone, although completely formed, yet is changing its earth, and probably every other part. This effect, however, is much slower than in the growing bone. This would show that the madder does not act as a dye upon the earth which is already deposited in the bone, but only upon that matter that is every day deposited; and as there is a great deal more deposited in a young bone than in an old one in a given time, in the same proportion must it dye sooner than an old one. The new matter that is deposited in an old bone is to make up for the waste that is daily going on in it; but in a very old bone the waste is more than the repair[1].

Bones would seem to have but very little sensibility. This is best known in the fractured patella; where generally there is no contusion, no splinters to run into sensible parts, and nothing torn but what is also insensible. People who meet with such an accident, seldom complain of pain when it happens. It is similar in this respect to the rupture of the tendo Achillis[2].

The number of bones should be reckoned according to the number of distinct cartilages which ossify; for, in general, wherever Nature intended a bone, she first made a cartilage of the shape of the intended bone. Yet this is not universal; for I believe in none of the bones of the head, except the occipital and sphenoid bones, is there a cartilage: the others being formed in membrane; and even in the exceptions above mentioned it is only at the union of the ossifications that we find cartilage: in their circumference we find the bony rays shooting out into membrane. From this mode of numbering bones, we see that the bones called 'occipitale' and 'sphenoides' are but one bone. However, as a general principle, it appears the best; for we find it almost every where else in the body. Therefore it seems improper to give the parts of one bone in the adult two, three, or four different names, because it

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[1] [The preparations resulting from the experiments on the growth of bone are Nos. 188—201, Phys. Series. See also the memoir on the same subject "From the Papers of the late Mr. Hunter," communicated by Home to the "Transactions of a Society for the Improvement of Medical and Chirurgical Knowledge," vol. ii. p. 277, 1798.]

[2] [An injury of which Hunter had personal experience.]

was formed of two, three, or four different ossifications. It would be much more proper to give the bone only one name, as, for instance, the 'os innominatum,' for two reasons; because the whole is really but one bone, and because it was formed in one cartilage[1]. This last would be no reason if we found that Nature sometimes formed two bones in one cartilage, and that they remained so through life; but this is never the case. However, we have an exception to distinct cartilages forming distinct bones; for the sacrum is one bone, although formed in several distinct cartilages, these being closely united together by substances which readily ossify.

Bones in young animals are often so soft, that they are not able to support the perpendicular weight of body; therefore they generally bend; those that soonest give way are the tibiæ and fibulæ. The direction in which they do bend is not constant; being sometimes forward, and often outward. When forward, it is generally higher up than when outward; for when outward it is generally just above the ankle: but this bend forward is not altogether from perpendicular pressure; the tendency to it is assisted by the contraction of the muscles behind. This bend, in the human subject, is produced gradually by pressure from above. That it is from pressure or some power applied beyond the strength of the animal or part, is evident from the case of a young leopard. It was chained by a chain about a yard long, and had always a vast desire to go out of the door: in all its efforts to get loose it pulled in one direction, pulling with one fore-leg, and pushing with the other, by which means the bones of the leg that he pushed with were bent outwards, exactly answering these two motions of the legs, and the motion of the animal.

Ossification of the cylindrical bones is supposed to begin like a ring in the middle of the cartilage; and this ring becoming broader, makes the length of the bone. But I have reason to believe this is only conjecture, arising from what a section of a cylindrical bone would show. For in a very young bone we never find the end of it hollow, although the middle of it may be so; but as the end increases in length, from being solid, it becomes hollow; this scooping out or excavation following the growth.

Cut off from the end of an older bone the proportion by which it exceeds the length of a younger one, and we shall find the cut end of

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[1] [Hunter, it will be seen, fails to appreciate the signification and value assigned in homological anatomy to the distinct points of ossification in the common cartilage of the compound bones which he cites. It is interesting, however, to find this approach to the verge of considerations which have subsequently exercised so strongly the anatomical mind.]

the older bone hollow. From this then we see that the greatest part of the bone is solid, and afterwards becomes hollow; therefore it is reasonable to think that the first ossification was solid, and then became hollow.

The bones are such parts that do not grow or increase in any part while that part is exposed to the air; therefore Nature has taken care to cover bones that are sound as soon as possible [if they are by any accidental circumstance exposed].

Bones are commonly hard in proportion to their length; for, in proportion to their length they are obliged to make the greater resistance. Any lateral bias, wrench, blow, &c. more easily breaks a long bone than a short one. It in all cases acts with a longer lever.

Animals whose bases of support and motion are formed of hard and solid parts, have them so joined as to allow of motion between them; which joints, in the formation of their parts, are so related to the application of the powers of motion, as to constitute what are called the mechanical powers or levers. A lever has the moving power, the centre of motion, and the resistance. And as these may be so placed with respect to each other as to vary their relative position as much as three numbers can, so are the joints in an animal variously formed. The joint of the foot upon the tibia is of all the three sorts. It is a lever of the first kind when we push anything with our toes; of the second kind when we raise anything with them; and of the third when we raise our body upon them.

In mechanics, without resistance there could be no such thing as motion; but in animals, where there is a self-moving power, this can act without any resisting point. But this self-moving power cannot be applied to other parts, even in the animal, without a fixed point of resistance. However, these self-moving powers, by their simple action within themselves, may produce immediately the effect, without one point resisting more than another; as [in the instance of] a worm simply contracting and bringing its two ends together, or contracting laterally, so as to push itself out, by which means it is elongated; but even here the one half of the worm may be said to be the fixed point or point of resistance to the other; but a worm can fix any part of its body to whatever it lies upon, and move towards that point. A circular muscle would appear to have no fixed point, only the power of contraction, or shortening itself; and from the figure the muscle is thrown into, it produces its effects; each portion becomes a fixed point to the other all round; therefore every moving body which acts mechanically, acts from some resisting power which may be called the fixed point, or centre of motion. But animals, more especially the compound ones, having a number of joints or movements [of parts of the skeleton] on each other, have so many fixed points; the larger portion becoming the fixed point to the smaller; until, at last, the whole body has its fixed point, or point of resistance to move upon. Animals that move upon the earth, have that for their fixed point; birds that fly have the air for their fixed point; and fishes have the water for their fixed point.

Besides these general fixed points of motion for the whole animal, each animal has a fixed point within itself from which the parts of the body take their principal motion. In the human body this fixed point seems to be in the joints of the thigh-bones; and being in the middle of the body, it must be common to the extremities; therefore we see that the trunk either moves on the legs, or the legs on the trunk. Besides this there are as many fixed points as there are joints; so that the body is to be looked upon as a chain of joints whose general centre of motion is in the joints of the thighs; but each has its centre of motion, which is always on that side next to the general.

The greater the motion in any joint, the less nice it is; therefore, where correctness and nicety is wanted, the parts of motion are divided into smaller movements; as, for instance, the bones of the fingers become shorter and shorter towards their terminations.

Of the Spine.—The spine in animals is that which is the basis of the whole body, on which everything is built. It gives support to the whole, and may be said to be like the keel of a ship—the first thing laid down, from which the whole superstructure is to arise. From its great length, it is necessary to have motion within itself; and, as it would be improper for it to bend at one part sufficiently for the required motion, more especially on account of the ribs and viscera, it is made up of a number of bones, that it might have an easy motion through the whole: this also protects the spinal marrow from being hurt by too quick a bend.

The other joints have no parts save for their simple motion; but the trunk has a great many, which prevents such motion.

The spine is straight in a fore view, because the two sides of the body are similar parts; but the back and fore parts not being similar, the spine is bent accordingly, to be able to support the different weights applied to it. However, this is observable principally in the human subject, owing to his erect position. That part of the spine to which the other bones of the pelvis are attached [the sacrum], is commonly nearly in the same line with the rest of the chain of bones; although, in most, it is a little bent so as to give space to the pelvis; but in the human it is thrown further back, in order that the thigh-bones might be brought perpendicularly under the spine, and at the same time the cavity of the pelvis not at all diminished: both could not have been done in any other way.

The canal of the spine is largest in the neck and loins[1]. This answers two purposes; first, it allows a greater motion in those parts without the medulla being hurt; secondly, it makes the parts stronger with the same quantity of matter: this is most remarkable in the loins.

In man the crooks of the spine vary in different parts, at different ages, of the same person. In the child it is most in the back, and is backward; owing, perhaps, to the weight of head; in the adult it is as much in the loins and is forward. This, perhaps, is owing to the weight of the thorax and head, and the loins being the most moveable part.

The ligaments between the vertebræ are stronger externally in proportion as they are removed from the centre of motion.

The trunk is made up of three parts, the head, thorax, and pelvis—all at a distance from one another; and this is common to all quadrupeds. It was necessary that these parts should have motion; therefore they are placed at some distance from one another, which makes the necessity for the neck and the loins.

The back-bones of animals differ very much respecting motion, and especially the degree of curving; they might be divided into the straight and curved. Horses, elephants, rhinoceroses, and ruminating quadrupeds, which only stand or lie, have spines of the straight kind. However, there is a gradation between the straight and the curved spine. The curved or bendible spine belongs to those animals which can sit, either upright as in man, or bowed forward; the monkey, dog, &c. forming the gradation between the one and the other.

Animals that have very long bodies, and are small[2], generally have their backs bent upwards, archways: the use of this must be to support the body as an arch is supported.

In quadrupeds and birds the ilium is a long bone, situated nearly at right angles with the thigh-bone, crossing its head like the upper part of the letter T; giving origin, along its whole sweep, but principally at its ends, to muscles which flex and extend the thigh-bone. The middle part of the ilium is so near the joint as to give but a small surface for

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[1] [*Vide* Mr. Henry Earle's paper thirty years after Mr. Hunter's death, for this single fact, Phil. Trans. 1822 or 1823.—W. C. Mr. Earle also regarded the expansion at the two ends of the neural canal in the neck-vertebræ of birds as an important element of his paper.—R. O.]

[2] [See the skeleton of the marten [*Mustela Martes*], No. 4152, and that of the sable [*Mustela zibellina*], No. 4168, Hunterian Osteol. Series.]

muscular attachment; therefore there is produced but little lateral motion. This position and formation of the ilium with respect to the thigh-bone is remarkable in the bird.

The reason for the great difference between the shape of the pelvis in man and other animals, is to give a circular sweep of origin to the muscles of the human thigh-bones; the pelvis being adapted to this purpose by the circular spreading position of the iliac bones, making a cone, the base of which expands over the thigh-bones. The acetabulum is to be considered as the apex: it is placed laterally, looking downwards and outwards, and gives a free scope to the motions of the thigh-bone. This position of the bone obliges the thigh-bone to be of a peculiar shape; at first it comes out nearly in the direction of the cone, forming what is called 'head' and 'neck;' it then bends down so as to give the legs a proper position for the support of the body.

This position of the head and neck gives principally a rotatory motion, upwards and downwards, which brings the body of the bone outwards and inwards; so that the rotatory motion of the head and neck, joined with the up and down motion, produces the conoid motion in the body of the bone.

The body of the thigh-bone makes with the neck an angle of 56°. This angle confines in some degree the motion of the thigh; for, on account of it, the body of the bone has not the quantity of motion that the neck has; or would have, if the neck were continued out in a straight line from the body.

The perpendicular column of the leg of a fowl is thrown under the centre of gravity [by the forward bend of the femur]. For, although the joint of the thigh is not, that of the knees is, under the centre. The thigh-bone is supported in that oblique position by muscles.

The scapula and clavicle generally move together; but sometimes the scapula moves without the clavicle. When both move together, they may be compared to a pair of compasses.

The motion of the wrist is chiefly flexion and extension: the flexion is between the radius and first row of the bones of the carpus; the extension is between the first and second.

The metacarpus is to be considered as the first set of bones; for they make the basis for the others to bend upon. The second set of bones, or first row of the fingers, becomes the basis of the other two; and the second row of bones of the fingers becomes the basis of the last of all. In proportion as these bones become shorter, they describe, in their movements, the section of a smaller circle. The tails of some animals are constructed upon this principle.

Of Ligaments.—Ligaments are parts commonly composed of strong materials which are flexible. Their strength has to be equal to the accidental force applied, tending to dislocate the parts which they unite. Most of our muscles, with their tendons, become, indeed, principally the ligaments in the motions of the joint, arising from their own action. But every joint is not sufficiently surrounded with muscles and tendons to guard it in every direction; therefore it must have ligaments as a substitute. The thigh-bone at the union with the pelvis, and the humerus at the union with the scapula, are so surrounded with muscles that it is hardly necessary for them to have ligaments, excepting to retain the synovia. However, as those large joints are subject to various motions, not produced by their muscles, it was necessary they should have ligaments of some strength; although these are not always equal to the force of such motions, which are commonly called accidental. The ligaments of joints are inserted at a distance from the moving point, in a proportion equal to the quantity of motion, which motion is always from the received bone, viz. the thigh-bone and the humerus. It is equally so in the ginglymus and conoid joints; for, in the ginglymus, the ligament is inserted at a great distance from the point of motion on the flexing and extending sides, but is much nearer to the lateral, and in the true conoid the ligaments are inserted at equal distances all round.

The vertebræ of the quadruped are never, in any action of the animal, in danger of being pulled asunder, but they are liable to be broken asunder; therefore the union of the two is such as is a hindrance to their being broken, the strong part of the union being exterior, and the weak one in the centre.

The simple motion in every joint is the sliding one; but from the difference in the articulations, and the different directions of the bones, different effects are produced, which have given rise to different classes of joints, and of course to different names for them[1].

[Practical Anatomy.]

Of the Arrangement of Anatomical Preparations.

Parts of animals are often so combined, in their connexions and uses, as to make it impossible to separate them so as to make a series of anatomical preparations, perfectly classed according to their uses only; the vesica urinaria, *e. g.*, is connected entirely with the kidneys, as to use; but is so connected with the penis, &c. as to situation, as to make them inseparable. The urethra belongs equally to both.

[1] [The work had not proceeded beyond the second chapter. The following is a supplemental one on practical anatomy, or the art of making and arranging anatomical preparations.]

In large animals we are obliged to have recourse only to parts to make preparations of, and for convenience; but in small ones we are led to preserve the whole, and expose as much as possible; which breaks in upon the arrangement and classing of specimens: but it is somewhat like nature herself; one property belonging to more animals than one[1].

On making Anatomical Preparations, by Injection, &c.

The proper house.—A skylight is very improper: a side- or front-light should be preferred.

The proper place for keeping Preparations.—Both wet and dry should be kept in a cool place. If on a ground floor, and towards the north, so much the better; as the evaporation from the wet, and the throwing out of the wax from the dry, at cut parts, will be less.

The proper subjects.—Animals which have been bled to death are not so fit for minute injections as those which have died a natural death, because the vessels contract to adapt themselves to the quantity of blood contained in the body while bleeding; and all the muscular parts contract after death; therefore, if there is no blood in the arteries, they will become almost impervious. In such cases, steep the parts for some time till a species of putrefaction begins to take place. The parts should likewise be gently squeezed, to relax the muscular contraction of the vessels. These two last circumstances should be punctually attended to; for if it is a part of a newly dead animal, it will not allow the injection to go so far as when the animal has been dead some time: but great care should be taken not to allow putrefaction to go too far.

Parts of bodies that are to be injected and shown in their natural form, should be parts of young and healthy subjects; as they will be less altered from their form than by disease, and the vessels will better bear the injection. If possible, the water that preparations should be steeped in should be distilled, for it preserves animal bodies above six times longer from putrefaction than common water; and by this means the parts will have time to become more free of blood, especially thick parts. If not distilled, it should be clear and often changed. If the part be suspended near the surface of the water, so much the better, as the part will not be allowed to soak in its own blood, which will gravitate to the bottom.

In all injections use a pipe as large as you can get into the vessel, as

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[1] [The degree in which Hunter overcame these impediments in carrying out his great idea of a physiological collection of anatomical preparations, may be estimated by a study of that part of his museum containing his dissections of animals of every class, and of plants; or of its Catalogue, 'Physiological Series,' 5 vols. 4to. 1833– 1840.]

it will allow the injection to move in a greater column, therefore faster, and will prevent stagnation.

Where a vessel is cut too short to fix a pipe in, in the common way, it is proper to pass a couple of pins through the mouth of the vessel, introduce the pipe between them, and tie the ligature below the pins. This also becomes more necessary where the vessel bears a large size in proportion to the pipe, as in the vena cava hepatica of an ox, elephant, &c. Also, where we are obliged to inject cavities from the side of the cavity itself,—as the urinary and gall-bladders, vesiculæ seminales, often the heart, and sometimes a large artery that has only been partially filled,—pins may be used, as in the case of vessels which are cut too short to be tied up in the common way. Also, where there is a hole in a cavity, as in the bladder, or in an artery or vein, the pins can be used with advantage.

Of Syringes.—They should not be too long and small, as they will cool the injection too fast; nor too short and thick, for they are then very inconvenient for many purposes, as injecting small parts, &c. There should be two sets of syringes, one for oily, and the other for watery injections. Syringes are, in general, too large. In injecting minutely, care should be taken that no air gets before the injection; to prevent which, before you fix the syringe into the empty pipe, pour some of the injection into the pipe till it is full, and then fix the syringe. Push the injection pretty quickly at first, until the vessel is full, and then gently, to prevent extravasation.

Of Injections, &c.—First, injections, with regard to subtleness, should always be fitted for the purposes intended; secondly, the nature of the injection to answer the design; and thirdly, its consistence should be considered, both when it is hot and when cold. As we generally make more at once than is used at one time, heating thickens and hardens it, and therefore its consistence must be tried every time before it is used.

Some injections require much more exactness in this respect than others; in corroded preparations we cannot be too nice in this respect, as the injection is to support itself afterwards without any coats of vessels.

Common Injection.—The corroding injections are too hard for many purposes, and the fine ones too soft: therefore we need something between them; *e. g.*—

℞. Resin, ℥ij.—Tallow, ℥ij.
Colour q. s. ft. Injectio.

These we generally use for parts to be dissected, as legs, arms, &c.

Oily Injections.—These are made of many kinds, as Ol. Terebinth., hog's lard, tallow, &c. The Ol. Terebinth. is rather too thin of itself;

but when joined with tallow two parts, they correct each other, as the one is too thin, and the other rather too thick. Butter or hog's lard make of themselves pretty good injection.

Watery Injections.—Glue dissolved in water alone makes a good minute injection. Before you dissolve it by heating it, steep it in water twelve hours; then heat it gently till the whole is dissolved; afterwards strain it and drop some of it on any cold substance, and you will know its consistence. When it is somewhat thicker than common jelly, it is of a proper consistence. 'Size' is better than 'glue' for white injection, being clearer. Isinglass, prepared in the same manner with the preceding, makes an injection similar to it. All fine injections require more colour than coarse ones; for, as it is to run into much smaller vessels, it often becomes more and more transparent, and therefore requires such a quantity of colour as to render it opake when it is most minutely diffused, either in very small vessels, or on any surface.

A watery or spirituous injection is best for injecting thin parts that are to be dried and rendered transparent; viz. all sorts of membranes, and such parts as seem to be membranous when dry, as the stomach, intestines, &c.

Preparing parts to be injected for Veins.—We can only inject the large trunks of veins in the extremities; for when we put a pipe into a vein and throw in our injection, it in general only passes in a straight line from that to the heart, for at the entrance of other veins into this vein there are generally placed valves which keep the injection in a straight line to the heart; and if these valves are not sometimes exactly at the mouths of collateral veins, yet you will generally find they are within an inch of it, so that you have only so much injected. However, on the foot and back of the hand the veins in general form an arch on both sides, and we have all the veins arising from this arch injected; but still this would not inject all the large veins if there were not other communications between the veins of different parts; but we find that a vein on one side shall send a canal of communication to a vein of the other side, which canal having no valves, the injection passes freely, and injects the veins of the other side.

Warm water should be injected into veins before injection, for two reasons; first, to warm the parts; and secondly (and indeed the most material), to wash out the blood, especially if the injection is of a white colour; and great care should be taken that all the water is squeezed out before you throw in your injection, or any air that may be in the veins; for these often make interruptions in the larger trunks. One would imagine that the air, water, or blood would be carried along the veins before the injection, and would be let out at the great trunk of the vein or at the heart, if it was a whole body; but practice shows us the contrary, and it is easily to be accounted for; viz. the small vein that you put your pipe into is not only to inject the vein leading from that in a straight line, but to inject many collateral ones. Now, if there be any air, water, or blood in any of the collateral veins, that air, &c. will be carried on towards the large trunk before the injection; but the injection will by this time have got into the large trunk beyond the mouth of this collateral vein, by means of the vein that led immediately from the pipe. This air, &c., then, being thrown into the large trunk, where there is injection both before and behind, it must make an interruption at that part; but the interruption will not rest here if you continue to throw in your injection, for it will be carried forwards by the succeeding injection, and it will at the same time forward the column of injection that is before it.

Now that we have explained the cause of one interruption, we can easily see how many may be formed, as there are more than one collateral vein. One would remedy this by throwing in the injection till all those collateral veins have communicated with the common trunk, and letting the injection run out at the other end, till the last interruption had come out at the end of the vein, and then tie up the end to keep the succeeding in; but we cannot always throw in so much injection by such a small pipe as one would in such cases; however, we always leave the end of the great vein open till we see the injection come out by it.

When the veins of a leg or arm are injected, they should not be handled or compressed while the injection is fluid in them, but should be hung up by their ends that are next the body. This will prevent the injection from getting out of the smaller veins into the large ones, because the valves will not allow it to return again, and of course will become empty.

The gravid uterus should be injected by both veins and arteries at one and the same time, so as to have them run nearly equal where the placenta adheres.

Of Corroded Preparations.

The whole affair of injecting for corrosion, or making corroded preparations, requires more attention than any one other method of making anatomical preparations. They are always intended for the common distribution of the larger vessels, and therefore in parts that cannot be dissected with any degree of perfection or accuracy. As the animal parts are to be destroyed, and only the injection saved, the injection is only to be considered as a cast, and the vessels the mould; therefore the great concern is the perfectness of the cast, and the goodness of its consistence for such purpose.

The substances for this purpose might be as various as any other in the art of casting, if our moulds admit of it. We might have casts of all the metals or any other substance that admits of fusion or fluidity in any way, and afterwards becomes solid; but such is the nature of most of the animal moulds, that they cannot support a heat sufficient to allow of carrying this art to any great length.

The parts to be injected are the first consideration. They must be extremely sound or free of all disease, and they should be very fresh or free from putrefaction. The parts to be injected should be taken out of the body with great care, so as to have the principal trunk or trunks of the different systems of vessels preserved for the fixing the pipes; for few parts that are injected for corrosion anastomose so freely as to admit such injections to pass from one branch to a neighbouring one; therefore there will be no more injected than the part to which this vessel went or supplied. Besides preserving the principal trunks, it gives distinctness to the different systems of vessels, and an elegance to the preparation. The different systems of vessels or cavities are to be considered, by way of a leading step to the different coloured injections.

The injection is the next consideration, and as it is wholly a piece of art, and the only thing which is to be saved, it becomes an object to carry it to the greatest perfection we can. The first property of an injection is fluidity at one time under certain circumstances, and solidity at another. The nearer a substance can be brought to these two states, the more it is calculated for an injection in this respect; but there are many substances which have these two properties to a great degree, yet the circumstances necessary to bring them to such a state may make them very unfit.

Every injection for this purpose owes its fluidity to heat, and its solidity to cold (excepting plaster of paris), therefore the degree of fluidity necessary, and the degree of heat the parts will admit of, are the things to be considered. The degree of solidity when cold is to be regulated according to the degrees of heat of the atmosphere in which the preparation is made or to remain in; for there are many substances, such as many of the metals, whose heat when fluid is by much too great for an animal substance, although very proper when cold; while there is another metal, viz. mercury, whose heat in a fluid state is very proper, but whose solid state is not to be procured by the heat of the atmosphere in which the preparation is made or to remain, nor indeed by any cold we are capable of producing. The degree of heat of an injection is to be that which an animal substance will bear without altering its texture, or at least very little; and the more fluid it is in this degree of heat, joined with a sufficient degree of solidity in a heat of 70° or 80°, the greatest heat of the climate of Great Britain, it is so far a proper injection. Another property when cold, besides solidity, is tenacity; for there are many substances which, when cold, become very brittle, and will not bend or yield to pressure, which renders them very unfit for casts of this kind; nor should they be such as will alter in tenacity *by time*, which is an effect arising from most substances that are volatile, therefore are bad ingredients in such injections; however, in some cases they may be admitted with advantage, as will be mentioned. Injections for such purposes should be such as do not immediately become solid upon being exposed to cold, or at least that degree of heat that the part can bear which is to be injected, for there are many substances that can be made very fluid by heat, but in the degree of 60° become immediately solid. Wax and tallow are of this kind.

As it will very often happen that the corroding injection may run more minutely in some vessels than others, it becomes necessary that we should be able to adapt our injections to the various purposes. This will in general arise from the smallness of the vessel, in proportion to its length, which is to be injected. If it is a part that has several vessels, some very large, and others very small, as in the liver, the large, viz. the vena portarum and vena cava, should be injected with firm injection, as a support to the small, and the small vessels, viz. the artery and duct, may be injected with a softer injection.

Wax, resin, turpentine varnish, and tallow, in proportions according to the kind of preparation, form the menstruum or body of the injection for receiving, when melted, the required colour.

The right consistency of our injection may be known by dropping a little of it, when melted, into cold water; and when soft, form it into the shape of a vessel, and put it into the water again: when quite cold, try to bend it. If it breaks, it is too hard; if it bends very easily, it is too soft. It must be of such a consistence as not to bend without some force. If it breaks, then you may be certain that there is too much wax; therefore some resin and perhaps a little tallow should be added. If it be too soft, then some more wax should be added. Those that have the turpentine varnish, the Venice turp., or oil of turpentine in them, must be tried every time they are heated; because they lose part of their volatile oil, and become too hard and brittle, and therefore want an addition of one of these ingredients.

Of the Colours.—To these injections add as much colour as makes them appear of a proper bright colour to the eye. Those generally used are vermilion, king's yellow, blue verditer and flake-white. Others may be used. They are in general to be mixed with the injections when melted; but there are some exceptions to this rule, particularly with regard to the verditer, and in some measure to the flake-white, for they both unite (at least in part) with the injection chemically, and effervesce; to prevent which we find it necessary to melt some of the ingredients alone, and add the colour to these before the others are added. The following experiments will particularize these exceptions.

1st. Blue verditer with tallow alone causes no fermentation. 2nd. Blue verditer with wax alone does not ferment. 3rd. Blue verditer with resin does ferment, therefore mix the verditer with the tallow or wax either alone or together, and afterwards add the resin, which causes a small fretting. If you use Ol. Olivar. instead of tallow, use it in mixing the colour as you did the tallow. If, instead of tallow, you use the turpentine varnish or Ol. Tereb., mix the colour first with the melted wax; then add either of those ingredients you intend to use, and then the resin. These observations are equally applicable to the flake-white.

When we make a white injection, instead of the yellow wax we use the white; it will not even then be of a good colour, unless we load the injection, and make it pretty thick with the colour. It would seem that we have not yet any good green colour; but as blue and yellow make a green, blue verditer, added to yellow wax or resin, gives us a fine green.

Treatment of Parts after being injected for Corrosion.—A part that is injected for corrosion, whose figure alters by taking it out of the body, should be put into its natural form when put into the acid, and into such a vessel as is best adapted for such a figure. The distance of time between the injecting and the putting it into the acid, should be just when the injection has taken a solid form, which it will do sooner or later in proportion to the size of the preparation. If it cannot be put into the acid before the injection is quite cold (from the want of acid), take care that you put it into the vessel it is to be corroded in, that it may take the right shape, and afterwards you may add the acid; but if both these rules should be neglected, and it is allowed to cool in a wrong position from its natural one, then it must be put into warm water till the injection has acquired that degree of softness as to allow the part to take its natural form in the vessel it is to be corroded in.

When you inject a part for corrosion in the summer, you must put it immediately into spirit of sea salt; because it will soon begin to putrefy, by which means the vessels will be either broken or bent by handling afterwards.

Of washing Parts after they are corroded.—After a part is sufficiently corroded, it is to be cleaned by pouring water upon it. This is best done by pouring it in a gentle stream from a tea-kettle till it seems quite clean, yet it will be afterwards necessary to immerse it in water, and move it pretty briskly, by which means you will be able to wash off a great many small pieces of its substance, and small pieces of broken branches that were entangled when out of the water.

Of Dry Preparations.

While preparations are drying that are afterwards to be varnished, it is necessary to have the parts so disposed that every part may easily be touched with a brush; for, if this is not attended to, it will very often happen that there will be corners and interstices which it is impossible to touch, but which were easily to have been got at or exposed when dissecting, by the flexibility of the parts. If preparations could be dipped into varnish, it would answer better than any other method, but that can hardly be done with large preparations, such as a whole body for the blood-vessels, nor even with a leg or an arm; and, indeed, these are the preparations which would require this attention most.

Preparations while drying should never be allowed to freeze, for in that operation the air is let loose or collected into larger parcels, which does not diffuse again in the thawing; therefore a vast number of small cavities are formed, and of course a vast number of reflecting surfaces like powdered glass, which takes off from the transparency of the preparation.

A part of some considerable size, such as the testicle of a horse, &c., which is to be dried, especially too if it is in the summer, should be particularly prepared for that purpose, independently of the exposition of its parts. The artery should be injected with water till it returns by the veins, and made pretty clear of blood, for blood first tends to putrefy. These should be injected with spirits of wine only, if it is afterwards to be injected with a watery injection; but if to be injected with an oily injection, it should be injected with oil of turpentine after having been injected with spirit, and then it may be injected with the intended injection. The spirit coagulates the juices, which is one method of preventing putrefaction, and permits evaporation. The oil of turpentine also prevents putrefaction, and permits evaporation.

Colours for dried Preparations.—Those preparations that are to be dried, such as stomachs, intestines, membranes of any kind, and more especially such as are thick in substance, such as hands, feet, &c. either for turpentine or not,—children for the blood-vessels, muscles, arms, legs, —in short any preparation that is to be dried, especially those that do not dry very transparent and of a light colour,—should be injected with vermilion, if we use red, for vermilion is the lightest red of any that can be called a good red; therefore it makes a greater contrast between the vessels and the thing itself. But the kind of injection will make a good deal of difference in the colour, for all reds become much deeper by being mixed with oily substances, therefore the colour that is fit for oil, is much too pale when mixed with water and spirits, and *vice versâ.*

Many parts of fishes that are intended for dry preparations should first be steeped in spirit; this coagulates all their juices, preserves them from putrefaction, and allows of a quicker evaporation, all of which are often absolutely necessary.

Of Varnishing.—Varnishing dry preparations has three advantages; first, it prevents their being destroyed by insects; secondly, it preserves them from the dirt, as any dirt will easier come off a smooth coat of varnish than off the preparation itself; and thirdly, it gives the preparation a much brighter colour, and makes the part shine by entering its pores, thereby rendering it more transparent. The varnish being a transparent body itself, and entering the pores, fills them up: thereby the whole becomes a more uniform mass, having fewer reflecting surfaces, and therefore the deeper-seated parts that are bright (viz. the injected vessels) are better seen. Varnishing preparations is as necessary a part as any, as it keeps them clean and free from insects; and for this last purpose it is necessary to be extremely nice: the parts that are easiest varnished are those which have least occasion for it, it being the hollow corners or crevices that require it most, as it is there the insects lay their eggs, the worms from which destroy the preparation. Insects often eat their way through the varnish into the preparation; to prevent which, dissolve corrosive sublimate in spirit of wine, and mix it with the varnish before it is laid on the preparation.

The spirit varnish is most proper for those preparations that are to be handled, because the gum that dissolves in spirit does not in water; so that the moisture of the hand does not soil it. It likewise does best for those preparations that have any grease in them; for it in some measure mixes with the grease, and therefore adheres more firmly to the preparation; whereas the watery gum does not, so that it rises in blisters.

Spirit varnish is best for corroded preparations; it is better than the copal, because it does not dissolve any of the injection on the surface, which is the case with the copal, and all the turpentine varnishes; and when they dissolve the wax on the surface of the smaller vessels, it almost goes through and through, by which means they bend or collapse.

Mr. Henry's copal varnish dries very readily, but when perfectly dry is apt to crack by bending the preparation. The cracks appear white and mealy, as if the gum had lost its cement by drying. If a little more tenacity could be given to it so as to avoid its cracking and not prevent its drying, it would be preferable to the copal varnish commonly used.

Of the Preparation of Bones.—After roughly removing the flesh, &c., the quickest way, without boiling, to clean them, is to put the bones into a tub, with a loose cover, so as to let the flies get to them; they will fly-blow them immediately, and in a fortnight's time they will have entirely destroyed the flesh. However, this can only be done in summer.

Bones that have been steeped in water, either after boiling or not, are generally either of a black greyish colour, if they have been steeped long enough, or they are of a pretty good white: these colours arise from an entire want of grease, and these colours are always brightest in the middle of the bone where there is the least grease. These are the most promising colours, for the white will remain and the grey or black will become white by being exposed to the air; but what is most valuable is the want of grease.

If bones are of a dark or dirty brown when taken out, we may be pretty sure that they have not a great deal of osseous matter; and are therefore light and bad bones. This colour is often attended with grease, but whether it is or not, it is a bad one; they never become white of themselves, and it is hardly possible to make them so by art; for they seem to be dyed, and that a little way into the bone; but it is always of a deeper colour near the surface than in the substance of the bone.

If they are taken out of a pretty bright or whitish yellow, or a little on the orange colour, we may be sure they will be greasy, especially if they feel slippery or saponaceous. This colour will be most at the ends of bones, and it often seems mixed with the dark brown, and is generally attended with a yellow transparency.

When this is the case, they have not lain long enough in water; and, indeed, there is a great chance against their ever becoming free of grease before the bones are spoiled by steeping, if they have lain so long already as to have destroyed the flesh. This colour, in general, attends a good bone, or in other words, a strong one.

The human flesh is longer in rotting than in any other animal; especially the tendons, ligaments, and cartilages; it becomes more hard by steeping, but in other animals it seems to dissolve. This is most so in old people.

Separation of Cuticle.—Putrefaction and boiling water separate the cuticle from the cutis; but putrefaction is the best; for boiling water does not do it so regularly over the whole.

Of the transparent Preparation of Bones.—Bones in many animals are a mixture of earth and animal matter; as the earth is in the form of a powder or calx it is opake. To render such a bone transparent, it is necessary that this earth should be extracted and nothing left but the animal substance. To do this, the bone should be steeped in an acid, with which the earth unites and dissolves. The acid should be so diluted as to have but little effect upon the animal part; however, the weakest acids will, in some degree, affect it, which is of some advantage, as it renders the preparation still more transparent.

The acid should be diluted so as only to feel a little sharp to the tongue. Perhaps common vinegar is as strong as it should be. Water is commonly the fluid the acid is diluted with, and is as proper as anything when the preparation is simply a bone that is to be put into it: but it is sometimes necessary that soft parts are also connected with the bone to complete the preparation. In such cases, to preserve the soft parts from putrefaction, it is proper to dilute the acid with spirit, which preserves the soft parts while the acid is extracting the earth.

If the quantity of liquid is too small to allow of a sufficient quantity of acid to dissolve all the earth in the bone, then more acid may be added to the same liquid when that which was first put is fully saturated, which will be in a day or two.

Vitriolic acid should never be used, as it does not dissolve the earth of bones, but unites with it in the form of selenites [sulphate of lime]. The marine [nitric] acid should be as pure as possible, or free from any vitriolic acid.

Of Wet Preparations.—Preparations should never be allowed to have any considerable tendency to putrefaction before they are put into spirits, because the part or piece putrefied does not coagulate so soon, nor so firmly, as the fresh; therefore you will have the spirits made or kept much longer foul from the oozing of the uncoagulable juices; but, where it is unavoidable, the spirit should be strong in proportion, especially if the mass be large. If the preparation is made in the summer, and is pretty large, it will be hardly possible to prevent putrefaction before it is properly steeped; therefore it will require, at first, either more spirit than common, or stronger.

Of the Colour of Wet Preparations.—As all parts of an animal are nearly of the same colour when deprived of their blood (excepting the skin and some glands, as the liver, which take much of their colour from the juice which they secrete), great care should be taken not to deprive such parts of their blood, which owe much of their distinction of parts to their colour; and in many such parts, instead of lessening such distinction, it ought to be increased. Supposing a tongue to be preserved for the interweaving of its muscular fibres (which is best seen from colour), the colour should be heightened; therefore, instead of being steeped in water, it ought to be steeped in a solution of nitre, which gives a brightness to the blood in the muscles, and makes the distinction between muscles and other parts more conspicuous. In a section of the proboscis of an elephant, this treatment has a good effect.

Preparations that are to be kept wet, and are steeped in water till all the colour is extracted, and therefore become white in themselves, should be injected with a colour redder than vermilion; for, if it is not a very vascular part, the vermilion does not add so much to it as some other reds do, and the part appears less vascular than it really is. In very vascular parts, where nothing is seen but vessels, as the inner surface of the stomach, &c., one would in those cases choose the colour that pleases the eye most.

Spirit, &c.—The liquors to be used should have one property in common, that of preserving the preparation from putrefaction, and should be transparent. Liquors should have different degrees of astringency. Some should be strong, so as to keep preparations in any form that they are put into; *e. g.* a bladder, when filled with spirit of wine and let stand for some time, should not collapse when opened to show its inside, but should retain its form; and particularly such preparations as have been sent home in spirits without having had any attention paid to their form: the second liquor for such should be as astringent as possible. The best thing is the joining of acid to rectified spirit of wine.

Unless for such purposes as above, the liquors should have little or no astringency; as that prevents many parts being seen from their being drawn together, prevents the natural softness of parts, coagulates the serum which produces a whiteness, where you want to show vessels of different colours; and it always produces a milkiness in the first liquor, and a white sediment from a coagulation of the serum that is squeezed out of the vessels, cavities, &c.

The spirit of wine is the liquor commonly used. The strength of the spirit must be according to the solidity and mass of the preparations; as muscles, some gelatinous fish, &c. Rectified spirit of wine is in general too strong, but some preparations require it, not for their preservation, but for their position.

Weak spirits may answer best in many cases, and one would naturally suppose in most cases; as, in most, only preservation is wanted. But we find by experience that a weak spirit is slow in coagulating the juices; therefore the spirit is almost always dirty, or there is a sediment of coagulated serum at the bottom, so as to require a vast number of shiftings before the whole of the juices are coagulated; more especially where the parts are not quite fresh. Such spirit as is weak might be improved by dissolving some alum in it. Besides their not coagulating the juices quickly enough, they do not coagulate them sufficiently; most of the preparations that were put up in gin, are in this manner milky, by having the juices partly coagulated and partly suspended. At the second and succeeding times of putting spirits to preparations, it is not necessary that it should be so strong as at the first. Proof spirits lowered one third will be strong enough.

Of exposing the different parts of a Preparation.—Besides the exposition of the different parts in the dissection, they should be exposed as much as possible when in the form of a preparation. In the wet preparation, it is often necessary to have bristles stretched from one part to another; bristles put into parts to point them out, as into the ducts of glands, &c. These, if there are many of them in the same preparation, should be of different colours; black and white we have naturally; but still it is frequently necessary to have a variety of colours; bristles take on a bad dye of green, blue, red, &c., but if painted, will do very well. Where bristles are too small, or too weak, quills may be used, or the hairs of a rhinoceros's tail, &c.

Such substances, however, are sometimes too short, therefore something else must be substituted, as wire—such as passing it through the body of a snake to give it a particular form, &c., but the wire should not be iron, as it becomes rusty. Brass and copper wire also corrode; but I suspect something else than spirits, viz. Volat. Alk. or Acid, &c. may do this.

Of suspending Preparations in Spirits.—The threads by which preparations are suspended should be as fine as possible, so as they are sufficient to bear the weight of the preparation, but which need not be so strong as to suspend it in the air, as it is much lighter in spirits. If a preparation is such as to keep its form without threads, and only needs suspension, yet it is best to use two threads; as, in looking at the preparation, it will then turn with the glass. These should be fixed to opposite points of the preparation, or it will not answer so well.

The threads used for very small light preparations, should be allowed to untwist themselves in water before they are used; otherwise they will twist themselves in the spirit and become as one thread, which makes all the parts suspended appear indistinct. A single thread of the silk-worm is in general strong enough for most, and does not twist of itself; but in turning about the preparation bottle, they will frequently twist, and will be with difficulty untwisted, if at all, unless the preparation is heavy. In such cases, therefore, where the threads are long and the preparation light, it will be an advantage to keep the threads asunder midway by a bristle, or some such thing.

Preparations, when first put into spirits to harden, should be well suspended, so as to keep as much of the form you intend as possible, as this form will not alter afterwards. But there is no occasion to trim the preparation neatly, because this is better done when the preparation is hardened and to be put into fresh spirits; one can then take off a number of edges, loose parts, and such as have been put out of their place by threads, &c. Preparations being generally taken out of water when put first into spirits, we find that, as the water and spirits do not immediately unite, the loose parts of the preparation cling close to the body of the preparation. If a preparation is put into spirits under such circumstances, it should be moved in the spirit till all these loose, villous or fringy parts hang as they should do. This must be done immediately, because the parts coagulate in their first form, and then it is impossible to make them hang loose afterwards.

Of Bladders, &c. for tying over the Bottle.—The first bladder should be very thin, to allow as little distance as possible between the bottle and the lead, as that is the space through which evaporation passes. It should be a little putrid, so as to have formed a little glue, which allows it to stick much more firmly to the neck of the bottle and to the lead than it otherwise would do. Very hot water poured upon a bladder will have nearly the same effect.

Of shifting Preparations.—When preparations are shifted from one spirit to another, they should be first washed in the old spirit to wash away any loose mucus, &c. If the spirit they are taken out of is very dirty and much tinged, the preparations in that case should be steeped in clean spirits for a day or two, till that tinge is taken out, before they are put up in clean spirits.

Of diseased Parts.—Many diseased parts should not be steeped in water, as the disease is often shown or illustrated by the colour of the part, such as inflamed and mortified parts. These should be put into pretty strong *solution of alum*, or into pretty strong spirits, to fix and coagulate the juices.

Of Embalming.

The embalming a royal personage is done in the following manner. Incisions are made into the thickest part of the thighs, legs, and loins, to allow the fluids to ooze out; and where the subject is at all dropsical, these should be made as early as possible to allow them to drain. The thorax and abdomen are to be opened, and the whole of their contents stripped down together, also the kidneys, in one mass, and put into clean water. The brain is to be taken out, and the cranial cavity filled with the 'coarse sweets,' and then sewed up again. The cavity of the abdomen and thorax is to be filled with the same, and sewed up in the usual way. The contents of the abdomen and thorax, with the brain, are to be dried a little; and, after the urn has had its bottom well covered with the 'coarse sweets,' they are to be put into it. The urn is then to be filled up with the same, soldered down, and the top screwed on. The urn is a cuble of about a foot and a half, lined with lead.

The quantity of cere-cloth is fourteen yards, of a green colour. The fingers are rolled up separately, in straps the width of a penny ribbon, and then altogether. The arms are rolled up in strips separately, and the feet and legs the same. The body is wrapped up in two pieces, and the face and head are covered with two pieces, and afterwards rolled over with strips in every direction. The legs are then to be brought together, and the two great toes tied, and then all rolled up in one; the arms are to be brought to the sides, and the whole body is to be enveloped in two pieces, each seven feet long; the whole making one mass without any appearance of neck being retained.

The gashes made in the muscles are to be filled up with the 'fine sweets,' previous to the limbs being rolled up in the cere-cloth. The body, being so enveloped, and all the edges being made to stick close together with a warm flat iron, is to be enveloped by a piece of white silk. The narrower this is the better, as it rolls so much better, beginning at the head, and going down and up till the whole is well covered with the white silk. The same is afterwards to be done with a piece of purple silk, and tied in four places with white ribbon and with bow-knots tied before. The purple is silk peculiar to the royal family. This embalmed body is then to be put into the coffin, which is previously partly filled, and afterwards entirely filled, with the sweets, and soldered down.

In this process, first binding up the limbs with linen rollers would allow the cere-cloth to be much more neatly applied, and stick better than it can be made to do to the skin.

The composition for the cerate for the cere-cloth:—

Bees-wax	aa 3lb.
Yellow rosin	
Mutton suet................	1 lb.
Powdered Verdigris..........	℥i.

Melt them together, and when cold knock it out of the pan, scrape the foul bottom, and melt it over again, and then dip the cloths, as follows:—

2	Pieces,	1 yard each, for the legs, separate.
1	„	1½ yard, for the legs together.
1	„	5 feet, for the shoulders.
1	„	2½ feet, for the head.
2	„	7 feet each, to wrap the body in.
2	„	¾ of a yard each, for the arms.
1	„	2 yards long, for rollers.

The cloth to be either Holland or Irish, a yard wide, about 3*s*. 6*d*. per yard[1]. The pieces to be the whole width. Put packthread to the corners when you dip them, and stand on a table to draw them easily out of the pan.

The fine Sweets.

Radic. Irid. Flor. cras pulv.	14 lb.
Cyper. long pulv.	12 ℥.
Calam. Aromat. pulv.	1 ℥.
Flor. Rosar. Rub. pulv.	2 lb.
Herb. Marjoram pulv.	12 ℥.
Ligni Rhodi pulv.	1 lb.
Cort. Limon. pulv.	6 ℥.
Caryoph. Aromat. pulv.	ix ℥.
Gum. Benzoin pulv.	18 ℥.
Styrac. Calam. pulv.	x ℥.
—— Labdan. pulv.	iv ℥.
Moschi veri pulv.	ii ℈.

The Sweets for the Coffin.

Flor. Lavend.	lbvij.
Marjoram Manip.	xxx.
Rosar. Rubr.	ij.
Herb. Thymi Manip.	xxiv.
Absynth. Roman. Manip.	xxiv.
Caryoph. Aromat.	℥ij.

The herbs and flowers are to be cut very small, the cloves coarsely powdered, and all mixed with six bushels of bran, and put up in two coarse linen bags.

[1] [Prices have changed with the growth of manufactures since the date of the above.]

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END OF VOLUME I.

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