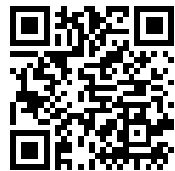

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Professor J. J. J. J. J. J.

with the author's sincere regards

LECTURES
ON
SURGICAL PATHOLOGY.

VOL. I.

THE
MUSEUM
OF
COMPARATIVE ZOOLOGY
AND ANATOMY
OF HARVARD UNIVERSITY
CAMBRIDGE, MASS.

LONDON:
WILSON and OGILVY,
Skinner Street.

1851
D

LECTURES

ON

SURGICAL PATHOLOGY,

DELIVERED AT THE

ROYAL COLLEGE OF SURGEONS OF ENGLAND,

BY

JAMES PAGET, F.R.S.,

LATELY PROFESSOR OF ANATOMY AND SURGERY TO THE COLLEGE :

ASSISTANT SURGEON AND LECTURER ON PHYSIOLOGY AT ST. BARTHOLOMEW'S HOSPITAL.

VOL. I.

HYPERTROPHY: ATROPHY: REPAIR: INFLAMMATION:
MORTIFICATION: SPECIFIC DISEASES.

LONDON:

LONGMAN, BROWN, GREEN, AND LONGMANS.

1853.



TO

P. M. LATHAM, M.D.

AND

GEORGE BURROWS, M.D.

WHOSE SKILL HAS BEEN PERMITTED TWICE TO SAVE MY LIFE,

WHOSE FRIENDSHIP ADDS LARGELY TO MY HAPPINESS,

AND TO WHOSE TEACHING

I SHALL ATTRIBUTE MUCH OF WHATEVER GOOD MY WORK MAY DO,

I dedicate these Volumes,

WITH GRATITUDE, AFFECTION, AND RESPECT.

P R E F A C E.

NEARLY all the Lectures in these volumes were delivered at the Royal College of Surgeons, during the six years, from 1847 to 1852, in which I held the office of Professor of Anatomy and Surgery to the College. So many listened favourably to them, that I venture to hope I am not wrong in thus enabling many more to read them. But, in offering them to this larger class, some explanation of their scope and plan seems necessary.

The circumstances of my election to the professorship indicated the Pathological Museum of the College as the appropriate subject of the Lectures; and the first portion of the Museum, devoted to the illustration of General Pathology, seemed to offer the best plan by which the knowledge acquired in a long study of the whole collection might be communicated.

The modes were many in which such a subject might be treated in lectures; but, as circumstances had decided the

subject, it seemed well to let them determine, also, the method, and to adopt that which was most natural to one engaged in the simultaneous practice of surgery and teaching of physiology. Thus guided, I designed to give lectures which might illustrate the general pathology of the principal surgical diseases, in conformity with the larger and more exact doctrines of physiology; and the plan seemed the more reasonable, because it was in accordance with the constant design of the great founder of the Museum.

The Museum limited, while it indicated, the subjects of the Lectures. They were, therefore, not constructed to form a system of surgical pathology: several subjects, which might fill considerable places in such a system, were scarcely alluded-to in them; and, although I have added some Lectures, which could not be conveniently included in any of the courses, yet I have not gone beyond the range of such pathology as a Museum may illustrate.

The wood-engravings are, for the most part, copied from the same specimens and drawings as were the diagrams used in the Lectures; and I wish them to be regarded as intended for only the same purpose as such diagrams may serve; viz. that of assisting the more difficult parts of the descriptions of the objects to which they refer.

I have endeavoured to make the Lectures less incomplete, and more correct, by the aid of numerous facts ascertained

since they were delivered, and have added to them many things which time, or their inaptness for oral delivery, obliged me to omit. Among these are the references to specimens and illustrations; as well as to numerous authors who could not, in speaking, be conveniently quoted, but whom I am now glad to acknowledge as instructors. And I will here offer my thanks to some, to whom my debts are more than would be expressed, even by referring to all the occasions on which their works have aided me in the composition of the Lectures. Such acknowledgments are due, especially, to Mr. Lawrence, Mr. Stanley, Professor Owen, and Dr. Carpenter, from whom, during many years of valued friendship, I have derived, at every interview, either knowledge, or guidance in observing and in thinking. I am deeply obliged, also, to all my colleagues on the staff of St. Bartholomew's, from whom the constant help that I receive adds daily to the debt of gratitude incurred during my pupilage. And there are many friends besides, to whom it is my happiness to be indebted for knowledge used in these Lectures, and whom I thank collectively, not because I owe them little, but because I cannot name them all, and cannot thank some without appearing ungrateful to the rest.

I desire, in conclusion, to express my acknowledgments to the Members of the Council of the College, both for the repeated honour they conferred on me by so often electing me to the Professorship, and for the kindness with which many of them devoted their valuable time to attendance

at the Lectures. The encouragement they thus afforded me makes me hope, that the labour with which I strive to justify their choice, may have some success in the promotion of scientific surgery.

HENBIETTA STREET,

CAVENDISH SQUARE :

May 30, 1853.

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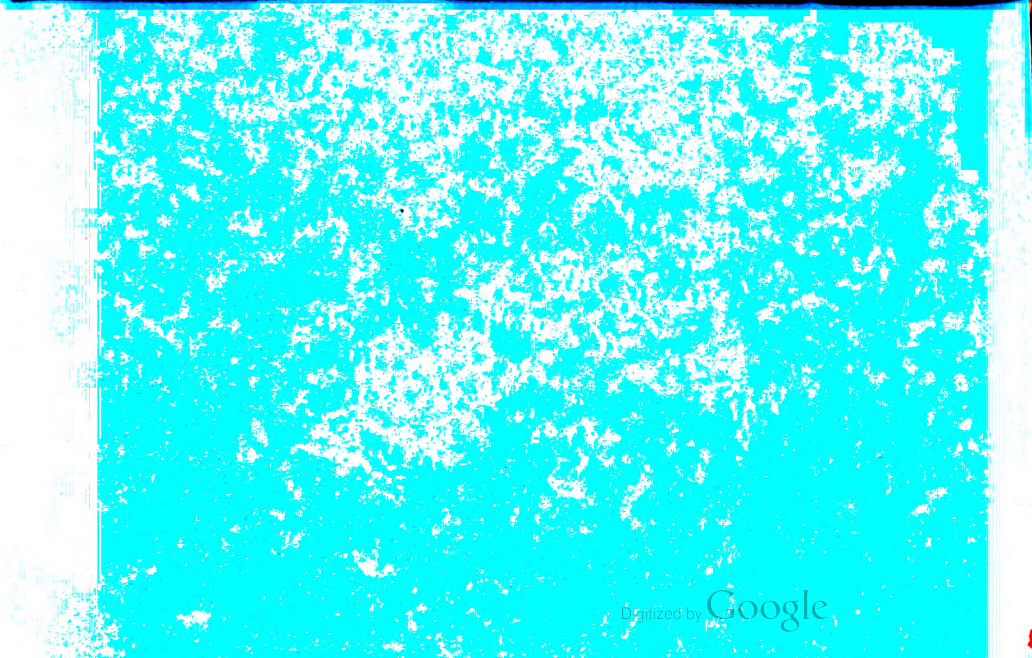
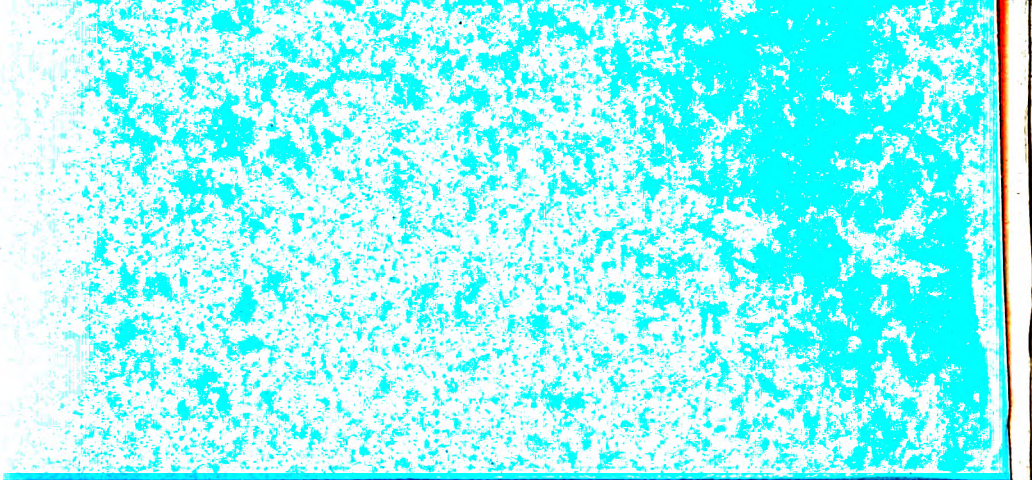
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LECTURES
ON
SURGICAL PATHOLOGY.

LECTURE I.

NUTRITION—ITS NATURE, PURPOSE, AND CONDITIONS.

MR. PRESIDENT AND GENTLEMEN,—I believe that I owe the honour of being elected Professor of Anatomy and Surgery to the College, chiefly, to my having been long engaged in the study of the pathological department of the Museum, while arranging and describing it, under the superintendence of Mr. Stanley, for the new Catalogue. I may, therefore, fairly suppose it to be the wish of the Council that, as the Museum is open to the examination of the members and pupils of the College, and of men of scientific pursuit, so should be the knowledge and the opinions which it has supplied or suggested to those who have had occasion to study it most deeply. For, indeed, to what thus grows out of the study of the Museum, the College has, in some measure, the right which the proprietor has to the produce of the cultivated soil. And when, through a long time past, your most learned Hunterian Professor Owen has every year brought in, from every source, so large a store of deep and wide-extending knowledge, of sagacious interpretation, and acute suggestion of

the ways of Nature, I scarcely wonder that some return should be looked for from an inferior labourer in the field.

The subjects on which I shall first beg your favourable hearing are those to the general illustration of which the first two series of preparations in the Pathological Museum are devoted—namely, hypertrophy and atrophy ; the simple excess, and the simple deficiency, of nutrition in parts. But let me previously speak of the healthy nutrition of the tissues, and, herein especially, of the formative process which maintains them by assimilation.

In the natural course of life, the formative process manifests itself in three modes, which, though they bear different names, and are sometimes described as if they were wholly different things, yet, probably, are only three expressions of one law, three effects of the same force operating in different conditions. The three, enumerating them in the order of their time, are development, growth, and assimilation or maintenance.

By development, we mean, generally, the process by which a tissue or organ is first formed ; or by which one, as yet imperfectly formed, is so changed in shape or composition as to be fitted for a higher function, or, finally, is advanced to the state in which it exists in the most perfect condition of the species.

We must carefully distinguish development from mere increase : it is the acquiring not of greater bulk, but of new forms and structures, which are adapted to higher conditions of existence. For example, when, in the embryo, groups of nucleated cells are changed into bundles of muscular fibrils, there is not, necessarily, an increase of size ; or, if there be, there is something more ; there is a change of texture, and an acquirement of power, adapted to a higher state of existence : these constitute development. So, when, from the simple cavity and walls of the

embryonic digestive system, the stomach, intestines, liver, pancreas, and other organs are produced, these are developed ; there is increase, but, at the same time, something more than mere increase.

The distinction between development and increase, or growth, is well shown in this,—that, sometimes, even in instances in which they usually concur, the one proceeds without the other. I might quote many examples of this. I will choose two or three, which, at the same time, may illustrate some other striking facts. Among the malformations in the Museum of St. Bartholomew's Hospital (Series A, 121 and 123), are the brains of two adult idiots. They are equally diminutive, and of nearly equal size : but in one, so far as we can see, there is a due proportion of the several parts ; it is only too small : in the other, the parts are not well proportioned ; the posterior parts of the cerebrum do not half cover the cerebellum ; indeed, no posterior cerebral lobes appear to be formed. Herein we recognise something more than a checked growth ; for this truncation of the cerebrum indicates an arrest of its development at the time when its hinder lobes—the parts last produced, and peculiarly characteristic of the human brain—were only just beginning to be formed. Our explanation of this most interesting specimen must be, that, when the brain had attained that degree of development which, according to Professor Retzius,* is proper to the human foetus about the beginning of the fifth month, and corresponds with the completed development of the brain of lower mammalia, then its development ceased. But though in form it is like the foetal brain in the fifth month, yet, in all its dimensions, it is larger ; so that, although its development had ceased, its growth continued, and was not checked

* Arch. d'Anat. et de Physiol., Jan. 1846.

till the brain had attained the size of that of a mature fœtus. In this brain, therefore, we find at once defective development and defective growth; but in the other the development proceeded, and the growth alone was checked.

Again, for examples in which development was checked and growth proceeded even beyond its normal limits, we may examine some of the numerous malformed hearts in the Museum. One among them presents only a single cavity; no partition has been developed between its auricles or its ventricles; it is, in respect of its development, like the heart of a fœtus in the second month: but though its development was checked thus early, its growth continued, and it has more than the average size of the hearts of children of the same age. In another, development was arrested at a later period, when the septum of the ventricles was incompletely formed; the patient lived eleven years after birth; the development made no further progress, but the growth passed its ordinary bounds.

And, once more, for instances in which the development was normal and growth abnormal, you may examine such skeletons as those of O'Byrne the giant, and of Madlle. Cracami the dwarf, in the Physiological Museum. The one is eight feet high, the other only twenty inches: but if you compare these with the model skeletons which stand beside them, you will not find in the one a defect, nor in the other an excess, of development; the dwarf has not less than all the characteristic human forms, the giant has no more; but the one is defective, the other is excessive, in its bulk; the growth alone has been erroneous in both.

It is, then, in the change to a higher state of form or composition, that development differs from growth, the second mode of the formative process. In mere growth, no change of form or composition occurs; parts only increase in weight, and, usually, in size. In growth, there

is an addition of quantity, but no improvement in the quality, of a part; the power of the growing part increases with the growth, but is only more of the same power; so, in the attainment of manhood, the heart of the boy, having all its necessary parts, and all well-formed, acquires perfection by acquiring greater bulk, and, therewith, greater power.

Lastly, in the formative process, as it is normally manifested in the adult, *i. e.*, in ordinary assimilation or maintenance, parts only preserve their *status*. No perceptible change of size or weight ensues, no change of form or composition; sameness is maintained through the regular formation of new parts in the place of those which, in the ordinary course of life, are impaired, or die.

Such are the methods of the formative process in the nutrition of organs. I shall have to show in future lectures, that some of the terms just used are, in a measure, conventional and arbitrary; that some instances of what we call development, *e. g.*, that of cartilage into bone, are not in every sense justly so named; and that the sameness, which is maintained in the adult body, fades into a gradual degeneration. But, for the present, the terms that I have used may suffice. It is convenient, also, to think of the three methods of formation, as if each might be separately manifested; yet, probably, they are always concurrent; the maintenance of whole organs being achieved only by the constant development and growth of new elemental structures in the place of those that are outworn.

Now, for the elucidation of this maintenance of parts by the constant mutation of their elemental structures, let me speak—

1st. Of the sources of impairment, or, if I may so say, of the wear and tear, to which every part of the body appears to be subject.

2dly. Of the conditions necessary for the healthy state of

the process of nutrition by which the results of the wear and tear are repaired.

3dly. Of the formative process itself.

First, then, the deterioration of the body may be traced to two principal sources; namely, the wearing-out of parts by exercise, and the natural deterioration or death of the elemental structures of every part or organ, independent of the decay or death of the whole body, after a certain period of existence.

From the first of these, the wearing-out of parts by exercise, it is probable that no tissue or part enjoys immunity. For although, in all the passive apparatus of the body—the joints, bones, ligaments, elastic vessels, and the like—much of the beauty of their construction consists in the means applied to diminish the effects of the friction, and the various pressures and stretchings to which they are subject, yet, in enduring these at all, they must be impaired, and, in the course of years, must need renewal. Doubtless, however, the waste of these parts by exercise is much less than that of the more active organs, such as the muscles, and, perhaps, the nervous system. With regard to the muscles, it is clear that chemical decomposition and consumption of their substance attend their continued action. Such action is always followed by the increased discharge of urea, carbonic acid, and water. The researches of Helmholtz* show, that the muscles themselves, after long-repeated contractions, are changed in chemical composition; and those of G. Liebig,† have detected and measured the formation of carbonic acid in them during similar contractions.

We have nearly similar evidence of the impairment of the

* Müller's Archiv, 1845, p. 72.

† Ibid. 1850, p. 393.

nervous system by prolonged exertion of its power. We have, indeed, no proof that the simple conduction of an impression through a nervous cord can affect in any way its composition or its structure; but the abundance of phosphates occasionally discharged with the urine, after great mental exertion, shows that the various acts of the mind impair the brain through which they are manifested. To this point tend, also, the researches of Dr. Bence Jones,* who has shown that the excretion by the kidneys of a large quantity of phosphate salts is usual in acute inflammation of the brain. And to this conclusion, that mental exercise, whether perceptive or active, impairs the structure of the brain, we might be led by our sensations and by our knowledge of the nature of the Mind. For to the principle, the immaterial thing, we cannot ascribe a weariness; it cannot be obnoxious to waste or to decay: mental fatigue is only what the Mind feels of an impaired state of the brain, and the recovery from what we call a weary mind is the restoration, not of the Mind itself, but of the organs which it feels, which connect it with the external world, and in which, during tranquil sleep, the reparative nutrition goes on undisturbed.

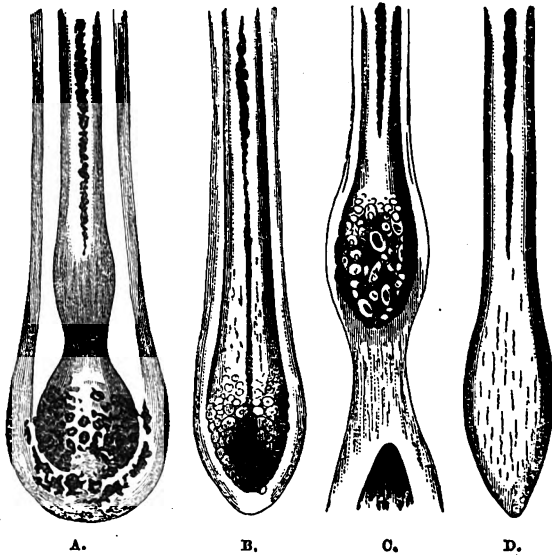
It is, further, probable that no part of the body is exempt from the second source of impairment; that, namely, which consists in the natural death or deterioration of the parts (independent of the death or decay of the whole body) after a certain period of their life. It may be proved, partly by demonstration, and partly by analogy, that each integral or elemental part of the body is formed for a certain natural period of existence in the ordinary conditions of active life, at the end of which period, if not previously destroyed by outward force or exercise, it degenerates and is absorbed, or dies and is cast out;

* Med. Chir. Trans. Vol. xxx. p. 20.

needing, in either case, to be replaced for the maintenance of health.*

The simplest examples that I can adduce of this are in the hair and teeth; and in the process which I shall describe, and illustrate with the annexed diagram, we seem to have an image in which are plainly marked, though, as it were, in rough outline, all the great features of the process by which tissues are maintained.

FIG. 1.



An eyelash which naturally falls, or which can be drawn out without pain, is one that has lived its natural time, and has died, and been separated from the living parts. In its

* Hunter (Works, vol. iii. p. 495), and Treviranus (Biologie, B. iii. p. 482), may be thought to have had some insight into this important law; but the merit of having first maintained in terms nearly similar to the above, and as more than an hypothesis, that "each part of the organism has an individual life of its own," and "a limited period of existence," belongs to Dr. Carpenter.—Principles of Human Physiology, 3d edit. page 623.

bulb such an one will be found very different from those that are still living in any period of their age. In the early period of the growth of a dark eyelash, we find its outer end almost uniformly dark, marked only with darker short linear streaks, and exhibiting no distinction of cortical and medullary substance. Not far from its end, however, this distinction is plainly marked; dark as the cortical part may be, the medullary appears like an interior cylinder of much darker granular substance: and in a young hair this condition is continued down to its deepest part, where it enlarges to form the bulb. (Fig. 1. A.) Now this enlargement, which is of nearly cup-like form, appears to depend on the accumulation of round and plump nucleated cells, which, according to their position, are either, by narrowing and elongation, to form the dry fibro-cells of the outer part of the growing and further protruding shaft, or are to be transformed into the air-holding cells of the medullary portion. At this time of most active growth, both cells and nuclei contain abundant pigment-matter, and the whole bulb looks nearly black. The sources of the material out of which the cells form themselves are, at least, two; namely, the inner surface of the sheath, or capsule, which dips into the skin, enveloping the hair, and the surface of the vascular pulp, which fits in a conical cavity in the bottom of the hair-bulb.

Such is the state of parts so long as the growing hair is all dark. But, as it approaches the end of its existence, it seems to give tokens of advancing age, by becoming grey. (Fig. 1. B, C.) Instead of the almost sudden enlargement at its bulb, the hair only swells a little, and then tapers nearly to a point; the conical cavity in its base is contracted, and hardly demonstrable, and the cells produced on the inner surface of the capsule contain no particle of pigment. Still, for some time it continues thus to live, and grow, and we

find that the vigour of the conical pulp lasts rather longer than that of the sheath or capsule ; for it continues to produce pigment-matter some time after the cortical substance of the hair has been entirely white, and it is still distinct, because of the pigment-cells covering its surface.

At length the pulp can be no longer discerned, and uncoloured cells alone are produced, and maintain the latest growth of the hair. With these it appears to grow yet some further distance, for we see traces of their elongation into fibres or fibro-cells, in lines running from the inner surface of the capsule inwards and along the surface of the hair ; and we can always observe that the dark column of medullary air-containing substance ceases at some distance above the lower end of the contracted hair-bulb. (c, d.)

The end of all is the complete closure of the conical cavity in which the hair-pulp was lodged ; the cessation of the production of new cells ; and the consequent detachment of the hair as a dead part, which now falls by the first accident ; falls, sometimes, quite bare and smooth on the whole surface of its white bulb, but sometimes bringing with it a layer of cells detached from the inner surface of the capsule. (d.)

Such is the life of a hair, and such its death ; which death, you see, is natural, spontaneous, independent of exercise, or of any mechanical external force, the natural termination of a certain period of life. Yet, before it dies, provision is made for its successor ; for when its growth is failing, you often find, just below the base of the old hair, a dark spot, the germ or young pulp of the new one ; it is covered with cells containing pigment, and often connected by a series of pigment-cells with the old pulp or capsule. (Fig. 1, c.) And this appears to be the product, as it were an offshoot, from some portion of the capsule of the old hair ; for

though it may sometimes appear only in the form of a conical pulp, yet more often, I think, it shows signs of connection with the capsule, and the cone is only more evident than the rest because of its covering of dark cells.*

I believe that we may assume an intimate analogy between the process of successive life and death, and life communicated to a successor, which is here shown, and that which is believed to maintain the ordinary nutrition of a part. It may be objected, indeed, that the death and casting-out of the hair cannot be imitated in internal parts ; but we are not without an example in which the absorption of a worn-out internal particle is exactly imitated in larger organs, at the end of their appointed period of life. I adduce the instance of the deciduous or milk-teeth.

We trace each of these developed from its germ, and, in the course of its own development, separating a portion of its capsule for the germ of its successor : then each, having gained its due perfection, retains for a time its perfect state, and still lives, though it does not grow. But at length, as the new tooth comes, the deciduous tooth dies, coincidentally, not consequently ; or rather, the crown of the old tooth dies, and is cast out like the dead hair ; while its fang, with the bony sheathing, and the vascular and nervous pulp, degenerate, and are absorbed. It is here especially to be observed, that the degeneration is accompanied by some spontaneous transformation of the fang ; for it could not be absorbed unless it were first so changed as to be soluble.

* This account of the change of the hair is confirmed by the much more minute description of Kölliker (*Mikrosk. Anatomie*, B. ii. p. 141). His observations were made chiefly in the young child, mine in the adult ; but, doubtless, his account of the complete continuity of the sheath of the new hair with that of the old one, of the gradual extrusion of the old hair, and of most of the details of the process, might be added to what I have described.

And it is degeneration, not death, which precedes its removal; for when a tooth-fang really dies, as that of the second tooth does in old age, then it is not absorbed, but is cast out entire, as a dead part.

Such, or nearly such, it seems almost certain, is the process of nutrition everywhere: these may be taken as types of what occurs in other parts; for these are parts of complex organic structure and composition, and the teeth-pulps, which are absorbed as well as the fangs, are very vascular and sensitive, and, therefore, we may be nearly sure, are conformed to only the same laws as prevail in all equally organized parts.

Nor are these the only instances that might be adduced. We see the like development, persistence for a time in the perfect state, death, and discharge, in all the varieties of cuticles, with which, also, we may connect the example of the gland-cells; and in the epidermis we have, as in the teeth, an evidence of chemical change in the old cells, in the very different influence which acetic acid and potash exercise on them and on the younger cells, making these transparent, but leaving them scarcely changed.

These things, then, seem to show that the ordinary course of each elementary organ in the body, after the attainment of its perfect state by development and growth, is, to remain in that state for a time; then, independently of the death or decay of the whole body, and, at least in a great measure, independently of its own exercise or exposure to external violence, to die or to degenerate; and then, being cast-out or absorbed, to make way for its successor.

It appears moreover very probable, that the length of life which each part is to enjoy is fixed and determinate, though, of course, in some degree, subject to accidents, which may shorten it, as sickness may prevent death through mere old age; and subject to the expenditure of life in the

exercise of function. I do not mean that we can assign, as it is popularly supposed we can, the time that all our parts will last ; nor is it likely that all parts are made to last an equal time, and then to be changed. The bones, for instance, when once completely formed, must last longer than the muscles and other softer tissues. But, when we see that the life of certain parts is of determined length, whether they be used or not, we may assume, from analogy, the same of nearly all.

For instance, the deciduous human teeth have an appointed duration of life : not, indeed, exactly the same in all persons, yet, on the whole, fixed and determinate. So have the deciduous teeth of other animals. And, in all those numerous instances of periodical moulting, of shedding of the antlers, of the entire desquamation of serpents, and of the change of plumage in birds, and of the hair in mammalia ; what means all this, but that these organs live their severally appointed times, degenerate, die, are cast-away, and in due time are replaced by others ; which, in their turn, are to be developed to perfection, to live their life in the mature state, and to be cast-off? We may discern the same laws of life in some elementary structures ; for example, in the blood-corpuscles, of which a first set, formed from embryo-cells, disappear at a certain period in the life of the embryo, being replaced and superseded by a second set formed from lymph-corpuscles. And in these, also, we may see an example of the length of life of elemental parts being determined, in some measure, by their activity in function ; for if the development of the tadpole be retarded, by keeping it in a cold, dark place, and if, in this condition, the function of the first set of blood-corpuscles be slowly and imperfectly discharged, they will remain unchanged for even many weeks longer than usual : their individual life will be thus

prolonged, and the development of the corpuscles of the second set will be, for the same time, postponed.*

The force of these facts is increased by the consideration of the exact analogy, the almost identity, of the processes of secretion and nutrition ; for in no instance is the fact of this limited life of individual parts more clearly shown than in the gland-cells, by which periodical secretions are elaborated. The connecting link between such gland-cells and the most highly organized parts, as well as a manifest instance of determinate length of life and natural death, is found in the history of the ova. These attain their maturity in fixed successive periods of days : they are separated (as the materials of several secretions are) while yet living, and with a marvellous capacity of development, if only they be impregnated during the few days of life that remain to them after separation ; but, if these days pass, and impregnation is not effected, they die, and are cast out, as impotent as the merest epithelial cell.

Now from these cases it is not by a far-fetched analogy that we assume the like mortality in all other tissues ; and that this is the principal source of impairment, and of change for the worse, which every part of the body has within itself, even in the most perfect state, and in the conditions most favourable to life. And I may anticipate a future subject of consideration, by saying that the application of these truths is of some importance in practical pathology ; inasmuch as the results of this degeneration of parts, at the close of their natural term of life, may be mingled with the effects of all the morbid processes by which the natural nutrition of a part is hindered or perverted. Hence, at least in part, the long-continuing or permanent loss of power in

* See Kirkes's Physiology, pp. 65 and 290.

an organ (say a muscle) which has been disused, or has been the seat of inflammation. This loss is not wholly due to a primary disease of the fibre; in part, it is because the inflammatory process and the organisation of the morbid exudation exclude the ordinary process of nutrition; and the muscular fibres, which now, in the ordinary course of life, degenerate, are not replaced, or are imperfectly repaired.

Of the results of these natural and unrepaired degenerations of tissues I shall speak more hereafter. Let me now consider the conditions under which the repair of parts thus deteriorated is effected; for it is against the effects of these natural deteriorations that the process of nutrition in the adult is chiefly directed; and it appears to be by the disturbance or removal of certain necessary conditions, more often than by any suspension or perversion of itself, that error is engendered in the process of formation. And, in speaking of these conditions of healthy nutrition, I shall take leave occasionally to diverge, even very far, into the consideration of certain points of interest in the general physiology of the process.

Doubtless the conditions necessary to the normal nutrition of parts are very many: but the chief of them are these four:—

1. A right state and composition of the blood or other nutritive material.
2. A regular and not far distant supply of such blood.
3. (At least in most cases) a certain influence of the nervous system.
4. A natural state of the part to be maintained.

And, first, of the right state of the blood, I may observe that I use the expression "right state" rather than "purity," because, if the latter be used, it seems to imply that there is some standard of composition to which all blood might

be referred, and the attainment of which is essential to health ; whereas the truth seems rather to be, that, from birth onwards, the blood and tissues of each creature are adapted to one another, and to the necessary external circumstances of life, and that the maintenance of health depends on the maintenance and continual readjustment of the peculiarities on which this exact adaptation depends.

The necessity for this right or appropriate state of the blood, as a condition of healthy nutrition, involves of course the necessity for the due performance of the blood-making and blood-purifying functions ; it requires healthy digestion, healthy respiration, healthy excretion. Any one of these being disturbed, the formative process in a part or in the whole body may be faulty, for want of the appropriate material. But, important as these are, we must not let the consideration of them lead us to forget that there is something in the blood itself, which is at least as essential to the continuance of its right and healthy state as these are, and which is, indeed, often occupied in correcting the errors to which these, more than itself, are subject ; I mean the power of assimilation or maintenance which the blood possesses, in and for itself, as perfectly and at least as independently as any of the tissues. By this it is, that notwithstanding the diversity of materials put into the blood, and the diversity of conditions in which the functions ministering to its formation are discharged, yet the blood throughout life retains, in each person, certain characters as peculiar as those his outer features for the continual renewal of which it provides appropriate materials. And by this assimilative power of the blood it is that the tissues are continually guarded ; for by it many noxious substances introduced into the blood are changed and made harmless before they come to the tissues ; nor can any substance,

introduced from without, produce disease in an organ, unless it be such an one as can escape the assimilative and excretory power of the blood itself.

In this maintenance is the chief manifestation of the life of the adult-blood; a life, in all essential things, parallel and concurrent with that of the tissues. For in the blood we may trace all those which we recognize as signs and parts of life in the solids: we watch its development, its growth, its maintenance by the assimilation of things unlike itself; we find it constituting an adapted purposive part of the organism; possessing organic structures; capable of disease and of recovery; prone to degeneration and to death. In all these things, we have to study the life of the blood as we do that of the solid tissues; the life, not only of the structures of the blood, but of its liquid also; and as, in first development, the blood and tissues are made, of similar materials, in exact conformity with one another, so, through later life, the normal changes of each concur to maintain a like conformity and mutual adaptation. I cannot now dwell on these points;* but they will be frequently illustrated in the following lectures, and some of them at once, in what I have to say of the precision of adjustment in which the "right state" of the blood consists.

Notwithstanding its possession of the capacity of maintenance, the blood is subject to various diseases, in consequence of which the nutrition of one or more tissues is disordered. The researches of modern chemistry have detected some of these changes; finding excesses or deficiencies of some of the chief constituents of the blood, and detecting in it some of the materials introduced from with-

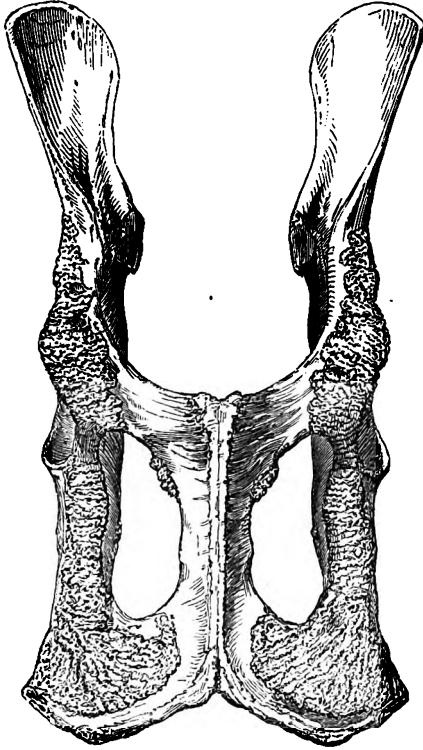
* They formed the subject of the course of Lectures delivered at the College in 1848, an abstract of part of which is given by Dr. Kirkes in his "Handbook of Physiology," p. 64, ed. 2.

out. But a far greater number of the morbid conditions of the blood consist in changes from the discovery of which the acutest chemistry seems yet far distant, and for the illustration and discussion of which we cannot adopt the facts, though we may adopt the language and the analogies, of chemistry. It is in such diseases as these that we can best discern how nice is that refinement of mutual influence, how exact and constant that adaptation, between the blood and tissues, on which health depends.

I know no instance so well adapted to illustrate this as the examples of symmetrical diseases. The uniform character of such diseases is, that a certain morbid change of structure on one side of the body is repeated in the exactly corresponding part on the other side. In the lion's pelvis, for example, which is sketched in the annexed diagram from a specimen, (No. 3030,) in the College Museum, multifiform as the pattern is in which the new bone, the product of some disease comparable with a human rheumatism, is deposited—a pattern more complex and irregular than the spots upon a map—there is not one spot or line on one side which is not represented, as exactly as it would be in a mirror, on the other. The likeness has more than Daguerreotype exactness, and was observable in numerous pairs of the bones similarly diseased.

I need not describe many examples of such diseases. Any out-patients' room will furnish abundant instances of exact symmetry in the eruptions of eczema, lepra, and psoriasis; in the deformities of chronic rheumatism, the paralyses from lead; in the eruptions excited by iodide of potassium or copaiba. And any large museum will contain examples of equal symmetry in syphilitic ulcerations of the skull; in rheumatic and syphilitic deposits on the tibiæ and other bones; in all the effects of chronic rheumatic arthritis, whether in the bones, the ligaments, or the

cartilages; in the fatty and earthy deposits in the coats of arteries.



Now, these facts supply excellent evidence of the refinement of the affinities which are concerned in the formative process. Excluding, perhaps, the cases of congenital defects that are symmetrical, and a few which seem to depend on morbid influence of the nervous system, it may be stated, generally, that all symmetrical diseases depend on some morbid material in the blood. You may find the proof of this position in papers written simultaneously by Dr. William Budd and myself;* and in Dr. Budd's essay you may find it nearly demonstrated, by a masterly discus-

* *Medico-Chirurg. Trans.* vol. xxv.

sion of the subject, that, in most of these cases, the morbid material enters into combination with the tissue which is diseased, or with the organised product of the morbid process. Now the evident and applicable truth in all these cases is, that the morbid substance in the blood, be it what it may, acts upon and changes only certain portions of what we might suppose to be all the very same tissue. Such a substance fastens on certain islands on the surfaces of two bones, or of two parts of the skin, and leaves the rest unscathed : and these islands are the exactly corresponding pieces upon opposite sides of the body. The conclusion is unavoidable, that these are the only two pieces that are exactly alike ; that there was less affinity between the morbid material and the osseous tissue, or the skin, or the cartilage, close by ; else, it also would have been similarly diseased. Manifestly, when two substances display different relations to a third, their composition cannot be identical ; so that though we may speak of all bone or of all skin as if it were all alike, yet there are differences of intimate composition ; and in all the body the only parts which are exactly like each other, in their mutual relation with the blood, are those which are symmetrically placed upon the opposite sides. No power of artificial chemistry can, indeed, detect the difference ; but a morbid material can : it tests out the parts to which it has the greatest affinity, unites with these, and passes by the rest.*

* Some of the differences here noticed are not permanent, but may seem to depend on the several parts of a bone, or of the skin, of a limb (for example), being in different stages of development or degeneration. The symmetrical parts of the tissue, being exactly alike, may be simultaneously and equally affected by a disease, while other parts of the same remain unaffected, till, in the course of time, they attain, by development or degeneration, the very same condition as the parts first affected. Then, if the morbid material still exist in the blood, these parts also become diseased : and so in succession

I might magnify the wonder of this truth by showing how exceedingly small, in some of these cases, must be the quantity of the morbid material existing in the blood. But I prefer to illustrate a fact which singularly corroborates the evidence, afforded by symmetrical diseases, of the refinement of the operations of the affinities, if we may so call them, between the blood and the tissues. The fact is that of certain blood-diseases having "seats of election." For example, in another lion's pelvis, No. 3024, diseased like that sketched above, not only is the morbid product just as symmetrical, but its arrangement is exactly similar: hardly a spot appears on one pelvis which is not imitated on the other. And these are only examples of a large class of cases of syphilis, rheumatism, and various skin-diseases, of which the general character is, that the disease is much more apt to affect one certain portion of a bone, or of the skin, or of some other tissue, than to attack any other portion. We are all in the habit of using the fact as an aid in diagnosis: but we may have overlooked its bearing on the physiology of nutrition. It proves, on the one hand, as the cases of symmetrical diseases do, that the composition of the several portions of what we call the same tissue is not absolutely identical: if it were, these diseases should affect one part of a bone or other tissue as often as another part, or should affect all parts alike. And it proves, on the other hand, a constant similarity, even an identity, of the morbid material on which each of these diseases depends,

may nearly the whole of a tissue. This view agrees very well with the fact that symmetrical diseases often spread, and so prove that a part which, in one week or month, is not susceptible of the influence of a morbid material, may, in the next, become as susceptible as that which was first affected. This susceptibility, however, may be due, not to normal changes, but to the influence which the diseased portion of the tissue exercises on those around it.

though it be produced in different individuals ; so that we may venture to predict, that whenever chemistry shall discover the composition of these materials, it will be found as constant and as definite as the composition of those inorganic substances which the science has most successfully scrutinised.

Moreover, Dr. William Budd has proved that, next to the parts which are symmetrically placed, none are so nearly identical in composition as those which are homologous. For example, the backs of the hands and of the feet, or the palms and soles, are often not only symmetrically, but similarly, affected with psoriasis. So are the elbows and the knees ; and similar portions of the thighs and the arms may be found affected with ichthyosis. Sometimes also specimens of fatty and earthy deposits in the arteries occur, in which exact similarity is shown in the plan, though not in the degree, with which the disease affects severally the humeral and femoral, the radial and peroneal, the ulnar and posterior tibial, arteries.

To conclude, these symmetrical diseases with seats of election, prove—

1st. That in the same person the only parts of any tissue which are identical in composition are, or may be, first, those which occupy symmetrical positions on the opposite sides of the body ; and next, those which are in serial homology.

2dly. That the portions of the bodies of different individuals which are identical, or most nearly so, in composition, are those in exactly corresponding positions.

3rdly. That even in different individuals the specific morbid materials, on which many of the diseases of the blood depend, are of identical composition.

It would be foreign to my purpose to enter now upon all the subjects of interest which are illustrated by these cases.

I may refer you again to the papers already mentioned, especially to Dr. Budd's. For the present it will be sufficient if I have proved (without pretending to explain or describe) the perfect and most minute exactness of the adaptation which, in health, exists between the blood and all the tissues ; and that certain inconceivably slight disturbances of this adaptation may be sources of disease. If this be proved, I shall not fear to be met with an objection against too great refinement in what I shall next say concerning some of the means by which that right state of the blood, which is appropriate to the healthy nutrition of all the parts, is attained and preserved.

LECTURE II.

THE CONDITIONS NECESSARY TO HEALTHY NUTRITION.

I NEED not dwell on the physiology of the processes of digestion, absorption, excretion, and others, which, on the large scale, serve in the development and maintenance of the blood. The admitted doctrines concerning these I must assume to be well known, while I proceed with the consideration of those minuter relations, in which the blood and the several tissues exercise their mutual influence, and by which each is maintained in its right state. And, first, let me endeavour to develop a principle, the germ of which is in the writings of Treviranus. His sentence is, that "each single part of the body, in respect of its nutrition, stands to the whole body in the relation of an excreted substance*." In other words, every part of the body, by taking from the blood the peculiar substances which it needs for its own nutrition, does thereby act as an excretory organ, inasmuch as it removes from the blood that which, if retained in it, would be injurious to the nutrition of the rest of the body. Thus, he says, the polypiferous zoophytes all excrete large quantities of calcareous and siliceous earths. In those which have no stony skeleton these earths are absolutely and utterly excreted; but in those in which they form the skeleton, they are, though retained within the

* Die Erschein. und Gesetze des organischen Lebens, B. I. p. 401.

body, yet as truly excreted from the nutritive fluid and all the other parts, as if they had been thrown out and washed away. So the phosphates which are deposited in our bones are as effectually excreted from the blood and the other tissues, as those which are discharged with the urine.

But Treviranus seems not to have apprehended the full importance of the principle which he thus clearly, though so briefly, stated; for it admits, I think, of far extension and very interesting application.

Its influence may be considered in a large class of out-growing tissues. The hair, for example, in its constant growth, serves, not only local purposes, but for the advantage of the whole body, in that, as it grows, it removes from the blood the various constituents of its substance, which are thus excreted from the body. And this excretion-office appears, in some instances, to be the only one by which the hair serves the purpose of the individual; as, for example, in the foetus. Thus, in the foetus of the seals that take the water as soon as they are born, and, I believe, in those of many other mammals, though they are removed from all those conditions against which hair protects, yet a perfect coat of hair is formed within the uterus, and before, or very shortly after, birth this is shed, and is replaced by another coat of wholly different colour, the growth of which began within the uterus. Surely, in these cases, it is only as an excretion, or chiefly as such, that this first growth of hair serves to the advantage of the individual. The *lanugo* of the human foetus is an homologous production, and must, I think, similarly serve in the economy by removing from the blood, as so much excreted matter, the materials of which it is composed.

Further, I think, we may carry this principle to the apprehension of the true import of the hair which exists,

in a kind of rudimental state, on the general surface of our bodies, and to that of many other permanently rudimental organs, such as the mammary glands of the male, and others. For these rudimental organs certainly do not serve, in a lower degree, the same purposes as are served by the homologous parts which are completely developed in other species, or in the other sex. To say they are useless, is contrary to all we know of the absolute perfection and all-pervading purpose of Creation ; to say they exist merely for the sake of conformity with a general type of structure, seems unphilosophical, while the law of the unity of organic types is, in larger instances, not observed, except when its observance contributes to the advantage of the individual. Rather, all these rudimental organs must, as they grow, be as excretions, serving a definite purpose in the economy by removing their appropriate materials from the blood, and leaving it fitter for the nutrition of other parts, or by adjusting the balance which might else be disturbed by the formation of some other part. Thus they minister to the self-interest of the individual, while, as if for the sake of wonder, beauty, and perfect order, they are conformed with the great law of the unity of organic types, and concur with the universal plan observed in the construction of organic beings.

And again,—the principle that each organ, while it nourishes itself, serves the purpose of an excretion, has an application of peculiar interest in the history of development. For if it be influential when all the organs are already formed, and are only growing or maintaining themselves, much more will it be so when the several organs are successively forming. At this time, as each nascent organ takes from the nutritive material its appropriate constituents, it will co-operate with the gradual self-develop-

ment of the blood, to induce in it that condition which is essential, or most favourable, to the formation of the organs next in order to be developed.

The importance of this principle will the more appear, if we connect with it another, equally characteristic of the minuteness of the relation between the blood and the tissues, namely, that the existence of certain materials in the blood may determine the formation of structures in which they may be incorporated.

This seems to be established, as a general law in pathology, by the cases in which diseased structures evidently incorporate materials that had their origin or previous existence in the blood. Such are most of those inoculable and other blood-diseases in which morbid organisms are produced; as vaccinia, variola, chancre, glanders, &c. The same law may be made very probable in physiology also. For example, when one kidney is destroyed, the other often becomes much larger, does double work, as it is said; and the patient does not suffer from the retention of urine in the blood: the full meaning of which (a well-known fact, and not without parallel) may be thus expressed:—The principal constituents of the urine are, we know, ready formed in the blood, and are separated through the kidneys by the development, growth, and discharge of the renal cells in which they are, for a time, incorporated. Now, when one kidney is destroyed, there must for a time be an excess of the constituents of urine in the blood; for since the separation of urine is not mere filtration, the other kidney cannot at once, and without change of size, discharge a double quantity. What, then, happens? The kidney grows; more renal cells develop, and discharge, and renew themselves; in other words, the existence of the constituents of the urine in the blood that

is carried to every part determines the formation of the appropriate renal organs in the one appropriate part of the body.

An analogous fact is furnished by the increased formation of adipose tissue in consequence of the existence of abundant hydro-carbon principles in the blood. Another, bearing on the same point, though not admitting of definite description, is the influence exercised by various diets in favouring the especial growth of certain tissues ; as the muscles, the bones, the hair, or the wool. Similar facts are yet more evident in the cultivation of vegetables, to which various materials are supplied, in the assurance that certain corresponding tissues will be consequently formed. And an evident illustration of the same principle is in the abundant formation of fruit on a branch in which the matured sap has been made to accumulate by *ringing*.

I add again, on this point, as on a former one, that the case as concerning nutrition is remarkably corroborated by the observation of similar facts in instances of secretions. Thus, the excesses of albuminous materials taken in food, if they be not incorporated in the more highly organized tissues, are excreted ; that is, they, or the materials into which they are transformed, enter into the construction of the transient tissue of the kidney or some excretory organ. The constituents of food, plainly as they influence the quantity and quality of milk, do so only by affecting, after their admission into the blood, the formation of the transient parts of the mammary gland-tissuè. Medicines, such as diuretics, that are separated from the body by only certain organs, are, for a time, we must believe, incorporated in the tissues of those organs.

These facts seem enough to make highly probable the principle I mentioned—namely, that the existence of certain materials in the blood may determine the formation of

structures into the composition of which those materials may enter. At any rate, they make it nearly certain for the more lowly organised tissues, and for the products of disease; and hence, by analogy, we may assume it for the other tissues. Even for the very highest, we may safely hold that a necessary condition of their formation is this previous existence of the peculiarly appropriate materials in the blood.

Now, if we combine these two principles—first, that the blood is definitely altered by the abstraction of every material necessary for the nutrition of a part, and secondly, that the existence of certain materials in the blood induces the formation of corresponding tissues, we may derive from them some very probable conclusions bearing on the questions before us. First, we may conclude that the order in which the several organs of the body appear in the course of development, while it is conformable with the law of imitation of the parent, and with the law of progressive ascent towards the higher grade of being, is yet in part, and in this more directly, the result of necessary and successive consequences: the formation of one organ, or series of organs, inducing, or supplying a necessary condition for, the formation of others, by the changes successively produced in the composition of the blood or other nutritive material. In other words, we may hold, in accordance with these principles, that the development of each organ or system, co-operating with the self-development of the blood, prepares it for the formation of some other organ or system; till, by the successive changes thus produced, and by its own development and increase, the blood is fitted for the maintenance and nutrition of the completed organism.

Secondly, I think that these principles may be applied to individual instances. They may suggest that certain organs

stand, in their nutrition, in a complementary relation to each other ; so that neither of them can be duly formed, or maintained in healthy structure, unless the right condition of the blood be induced and preserved by the formation of the other.

It is, of course, very difficult, or even impossible, to find instances by which this theory of complementary nutrition can be proved ; while, really, we neither know exactly what materials are necessary for the formation of any organ, nor have the means of detecting the presence of more than a very few of them in the blood. It is very well for the discussion of certain parts of physiology to say, for instance, that a muscle mainly consists of a material like fibrine ; but when we are considering the physiology of the formation of organs, we must remember that in every muscular fibre there are at least three different compounds—those of the sarcolemma, of the nucleus, and of the fibril ; that these are all equally essential to the formation of the fibre ; and that we know not the composition of any one of them, nor could detect the absence of any one of them from the blood, though the result of that absence might be to render the formation of a muscular fibre impossible.

But, though it may lack direct evidence, the theory seems, in itself, probable ; and there are many facts which we can explain by it so well, that they become evidence for it :—which facts, moreover, are fair subjects for theoretical explanation, since, I believe, they are admitted to be as yet wholly unexplained.

Among these is the general fact that a great change in nutrition rarely takes place in one organ at a time, but usually affects simultaneously two or more parts, between whose nutrition there is a manifest and constant connection, although there is little or no relation between their

external functions. Such, to take an instance from a large class, is the connection between the growth of various appendages of the integuments, and the development or maintenance of the genital organs. This appears to be a general rule. The growth of the beard at the period of puberty in man, with which we are so familiar, is more instructively represented in many animals: especially in birds. In these, as you know, at the approach of every breeding time, the genital organs begin to develop themselves for the season, as in man they do for the whole time of vigorous life. And, commensurately with this development, the plumage (especially in the male bird), becomes brighter and more deeply coloured, both by the growth of new feathers, and by the addition of colour to the old ones. The height and perfection of the plumage are coincident with the full development and activity of the reproductive organs; but, as in man, when the development of the genital organs is prevented, the development of the beard and all the other external sexual characters, is, as a consequence, hindered, so, in the birds, when the breeding season ends, and the sexual organs pass gradually into their periodic atrophy, at once the plumage begins to assume the paler and more sober colours which characterise the barrenness of winter.

So it is, also, at least in certain instances, in the mammalia, of which we have interesting evidence in the history of specimens presented to the museum of the College by Sir Philip Egerton. These show that if a buck be castrated while his antlers are growing and still covered with the felt, their growth is checked, they remain as if truncated, and irregular nodules of bone project from their surfaces. Or, if the castration be performed when the antlers are full-grown, these, contrary to what Redi said, are shed nearly as usual, at the end of the season; but in

the next season, only a kind of low conical stumps are formed in the place of antlers.*

I need not multiply examples : it is a general fact, that the development and activity of the reproductive organs have, as a consequence, or as a necessary coincidence, a peculiar development and active growth or nutrition of certain other structures ; which structures, therefore, form the external sexual characters, though their external functions stand in no apparent, often in no conceivable, connection with the generation of the species. The fact is not hitherto explained ; it is explicable, on the theory of complemental nutrition, by believing that the materials which, in the formation of these organs of external sexual character, are removed from the blood, leave or maintain the blood in the state necessary for the further development, growth, and active function of the proper sexual or reproductive organs. In other words, I would say, that where two or more organs are thus manifestly connected in nutrition, and not connected in the exercise of any external office, their connection is because each of them is partly formed of materials left in the blood on the formation of the other ; and each, at the same time that it discharges its own proper and external office, maintains the blood in the condition most favourable to the formation of the other.

If this theory be admissible, we may find through it the meaning of the commensurate development and nutrition of many other organs, which in their external functions

* This formation of imperfect antlers may depend on the accessory organs of reproduction being developed ; for these would not necessarily fail to be developed because the testicles were extirpated. And that the difference caused by castration is not due to the disturbance of nervous sympathies, is proved by the absence of any similar effect when the testes are only transplanted. See Berthold in Müller's Archiv, 1849, p. 42.

appear unconnected. Such are the concurrent development and activity of the thymus gland and the air-breathing organs, during the body's growth ; of the thyroid gland and the brain, (instances of commensurate development cited by Mr. Simon);* of the spleen and pancreas, (as pointed out by Professor Owen); and, I would add, of the embryo and the mammary gland; for the same theory may hold true concerning the formation of certain organs which are, finally, connected in their external functions.

In these, and other like cases, I think it will be hereafter proved that the several organs are, in their nutrition, complementary; that the formation of each leads to the production of some material necessary for the construction of the other; and that, as we may be sure of Treviranus' law, in general,—that each organ of the body, while it nourishes itself, is in the character of an excretion towards all the rest,—so, we may believe, more particularly, that certain organs are, mutually, as excretions from each other.

But, thirdly, if there be any probability in the principles I have endeavoured to illustrate, they must deserve careful consideration in the pathology of the blood. I shall have to illustrate them in this view in future lectures. At present I will only suggest, that if each part, in its normal nutrition, is as an excreting organ to the rest, then the cessation or perversion of nutrition in one must, by no vague sympathy, but through definite change in the condition of the blood, affect the nutrition of the rest, and be thus the source of "constitutional disturbance." If, in health, there be such a thing as complementary nutrition, it must, in disease, be the source of many sympathies in nutrition between parts which are not specially connected through

* Essay on the Thymus Gland; and Philosophical Transactions, 1844, Part 2.

the nervous system. If the condition of the blood can, in favourable circumstances, determine the formation of organisms incorporating its materials, we may study the characteristic structures of specific diseases as the evidences of corresponding conditions of the blood, and as organs which, by removing specific materials from the blood, affect its whole constitution, and either restore its health, or produce in it secondary morbid changes.

The extent of application that these principles admit of will, I trust, justify the distance to which I may seem to have diverged from my starting-point. Let me now return to it, and remind you that this long discussion grew out of the consideration of the first condition necessary for healthy nutrition,—namely, the right state of the blood; a state not to be described merely as purity, but as one of exact adaptation to the peculiar structure and composition of the individual: an adaptation so exact that it may be disturbed by the imperfect nutrition of a single organ, and that for the maintenance of it, against all the disturbing forces of the outer life of the body, nothing can suffice except continual readjustment by the assimilative power of the blood itself.

The second condition of which I spoke as essential to the healthy process of nutrition, is—

A regular supply of appropriate blood in or near the part to be nourished.

The proofs of the necessity of this condition must be familiar to all. Instances will at once occur to your minds, in which too little blood being sent to a part, it has suffered atrophy: others, in which the supply being wholly cut-off, mortification has ensued: others, in which the blood being stagnant in a part, has not efficiently contributed to its nutrition.

If I can give interest to this part of the subject at all, it is only by adducing interesting examples of the fact. Reserving for future lectures the examples of merely diminished and of perverted nutrition, I will mention now only some of the specimens in the Museums I have chiefly studied, which illustrate how the process of nutrition is wholly stopped by the absence or deficiency of fresh blood.

One of Mr. Swan's donations to the College-Museum (No. 1821) is the larynx of a man who, while in low health, cut his throat, and suffered so great a loss of blood that the nutrition became impossible in one of those parts to which blood is most difficultly sent; and before he died, his nose sloughed.

The case is like one which, you may remember, is recorded by Sir Benjamin Brodie.* A medical man wished to be bled, in a fit of exceeding drunkenness; and some one bled him,—bled him to three pints. He became very ill, and next day both his feet were mortified, from the extremities of the toes to the instep.

A specimen (No. 141), presented by Mr. Guthrie, exhibits a mortified, *i. e.*, a completely un nourished leg, from a case in which the femoral artery was obliterated near the groin through disease of its coats. The leg was amputated by Mr. Guthrie with justifying success; for the stump, though cut at some distance below the obliteration of the artery, did not slough; the collateral circulation was sufficient for its nutrition; and the patient, an elderly lady, died only of exhaustion.

For a similar, and very rare, example of sloughing after the obliteration of a main artery, I may refer to the case, described by Mr. Vincent, of a large slough in the very substance of one of the hemispheres of the cerebrum, in

* Lectures on Pathology and Surgery, p. 350.

consequence of a wound of the supplying common carotid, —a wound made by a tobacco-pipe thrust into the bifurcation of the carotid, and nearly closing its channel.*

A specimen in the Museum of St. Bartholomew's Hospital (Series i. 134) exhibits an instance of dry gangrene occurring in very unusual circumstances. A woman, 48 years old, died, under the care of Mr. Earle, having received some injury of the femur eighteen months before death. Whether it were a fracture, or, indeed, what it was, cannot now be said; but the injury was followed by enlargement of that portion of the wall of the femur with which the artery and vein are nearly in contact, as they pass in the sheath of the triceps adductor muscle. At this part, then, the vein is compressed, and the artery, though not distinctly compressed, appears to have been hindered from enlarging. The consequence was dry gangrene of the leg, which slowly destroyed life, and which had no other apparent cause than this.

And, lastly, let me refer to two specimens, which are as interesting in the history of surgery as in pathology. One is a tibia and fibula, the lower ends of which, together with the whole foot, perished in consequence of the obstruction of the circulation by an aneurism in the ham. It is an Hunterian specimen in the College-Museum (No. 710); and surely we may imagine that sometimes Mr. Hunter would contemplate it with pride, to think how rare such things would be in after times; for here is a strong contrast: the limb of a man who once had an aneurism, like the one which in the former case was so destructive, and on whom Hunter was permitted to confer fifty years of healthy life by his operation of tying the artery at a distance from the diseased part. The Museum of St. Bartholomew's owes this rare specimen and most interesting

* *Medico-Chirurgical Transactions*, Vol. xxix. p. 38.

relic to the zeal of my colleague, Mr. Wornald. The patient was the fourth on whom Mr. Hunter performed his operation. He was 36 years old at the time; and though the tumour was not large, yet the whole leg was swollen, the veins were turgid, and he was exhausted, and in such bad health, that the case seemed desperate; but he recovered, and lived, as I have said, fifty years. The artery was tied in the sheath of the triceps muscle; and in this operation, for the first time, Mr. Hunter did not include the vein in the ligature. He thus diminished exceedingly the danger of the defective supply of arterial blood. The preparation shows the whole length of the artery obliterated from the origin of the profunda, to that of the anterior tibial, and the aneurismal sac, even after fifty years, not yet removed, but remaining as a hard mass like an olive.*

Now, the supply of appropriate blood, of which these specimens prove the necessity, must be in or near the part to be nourished. We cannot exactly say how near it must be, but, probably, all that is necessary is, that the nutritive material should admit of being imbibed in sufficient quantity into the substance of the part. For imbibition must be regarded as the means by which all parts supply themselves with nutritive matter: thus deriving it from the nearest blood-vessels, and the blood-vessels themselves being only the channels by which the materials are brought near. The blood-vessels thus serve alike for the nutrition of the vascular, and, as we call them, the non-vascular, parts, the difference between which parts, in this regard, is really very little. For the vascular, the nutritive fluid is carried in streams into their interior; for the other

* The preparation is in Ser. 13, Sub-Ser. F. No. 4. The case is in the "Transactions of a Society for the Improvement of Medical and Surgical Knowledge," Vol. i. p. 138; and in Hunter's Works, Vol. iii. p. 604.



it flows on one surface: but in both alike, the parts to be nourished have to imbibe the nutritive fluid; and though the passage through the walls of the blood-vessels may effect some unknown change in the materials, yet all the business of formation is, in both alike, outside the vessels. Thus, in muscular tissue, the fibrils in the very centre of the fibre nourish themselves; yet these are distant from all blood-vessels, and can only by imbibition receive their nutriment. So, in bones, the spaces between the blood-vessels are wider than in muscle; yet the parts in the spaces nourish themselves, imbibing materials from the nearest source. And the non-vascular epidermis, though no vessels pass into its substance, similarly imbibes nutritive matter from those of the immediately subjacent cutis, and maintains itself, and grows. The instances of the cornea, the vitreous humour, and the peripheral part of the umbilical cord, are stronger, yet similar.

There is, therefore, no real difference as to the mode in which these tissues obtain their nutriment: and, sometimes, even the same tissue is in one case vascular, in the other not; as the osseous tissue, which, usually, when it is in masses or thick layers, has blood-vessels running into it; but when it is in thin layers, as in the lachrymal and turbinated bones, has not. These thin bones subsist on materials from the blood flowing in the minute vessels of the mucous membrane, from which, on the same plan, the epithelium derives nutriment on one side, the bone on the other, and the tissue of the membrane itself on every side.

It is worth while to remember this, else we cannot understand how the non-vascular tissues, such as the cornea, the hair, the articular cartilages, and the various cuticles, should be liable to diseases proper to themselves, primarily and independently. And, except by

thus considering the subject, we shall not be clear of the error and confusion which result from speaking of the "action of vessels," as if the vessels really made and unmade the parts. We have no knowledge of the vessels as anything but carriers of the materials of nutrition to and fro. These materials may, indeed, undergo some change as they pass through the vessels' walls: but that change is not an assuming of definite shape; the vessels only convey and emit the "raw material:" it is made up in the parts, and in each after its proper fashion. The real process of formation of tissues is altogether extra-vascular, even, sometimes, very far extra-vascular; and its issue depends in all cases chiefly, and in some entirely, on the affinities (if we may so call them) between the part to be nourished and the nutritive fluid.

The third condition essential to the healthy nutrition of parts, is a certain influence of the nervous system. It may be held, I think, that, in the higher vertebrata, some nervous force is habitually exercised in the nutrition of all the parts in or near which nerves are distributed; and that it is exercised not merely in affecting or regulating the size of the blood-vessels of the part, but, with a more direct agency, as being one of the forces that concur in the formative process.

Of late years, a current of opinion has run against the belief of this; and, of those who admit some influence of the nervous system upon the nutrition of parts, many do it, as it were, grudgingly and doubtfully. They hold that at most the influence is exercised only indirectly, through the power which the nervous system has of affecting the size of the blood-vessels; or that the nervous system influences only the degree, without affecting at all the mode, of nutrition in a part.

One chief argument against the belief that the nervous force has a direct and habitual influence in the nutritive processes is, that in plants and the early embryo, and in the lowest animals, in which no nervous system is developed, all nutrition goes on well without it. But this is no proof that in animals which have a nervous system, nutrition is independent of it: rather, even if we had no positive evidence, we might assume that in ascending development, as one system after another is added or increased, so the highest, and, highest of all, the nervous system, would be inserted and blended in a more and more intimate relation with all the rest. This would, indeed, be only according to the general law, that the inter-dependence of parts augments with their development: for high organization consists not in mere multiplication or diversity of independent parts, but in the intimate combination of many parts in mutual maintenance.

Another argument implies that the nervous force can manifest itself in nothing but impressions on the mind, and muscular contraction-force. So limited a view of the convertibility of nervous force, is such an one as the older electricians would have held, had they maintained that the only possible manifestations of electricity were the attractions and repulsions of light bodies, or that the electric force could never be made to appear in the form of magnetism, of chemical action, or of heat. We are too much shackled with these narrow dogmas of negation. The evidence of the correlation and mutual convertibility of the physical forces might lead us to anticipate a like variety of modes of manifestation for the nervous and other forces exercised in the living body.* We might anticipate, too, that, as the nervous force has its origin in

* See Carpenter on the Mutual Relation of the Vital and the Physical Forces, Phil. Trans., 1850, and General Physiology, p. 34.

the acts of nutrition by which the nerve-substance is formed, so, by reciprocal action, its exercise might affect the nutritive acts. As (for illustration sake) the completed blood affects all the processes by which itself was formed, so, we might suppose, would the nervous force be able to affect all the acts of which itself is the highest product.

But we need not be content with these probable deductions concerning the direct influence of the nervous force on the nutritive process. The facts bearing on the question seem sufficient for the proof.

A first class of them are such as show the influence of the mind upon nutrition. Various conditions of the mind, acting through the nervous system, and by nervous force, variously affect the formative processes in the whole body. There is scarcely an organ the nutrition of which may not thus be affected by the mind. It is hardly necessary to adduce examples of a fact so often illustrated; yet I may mention this one:—Mr. Lawrence removed, several years ago, a fatty tumour from a woman's shoulder; and, when all was healed, she took it into her head that it was a cancer, and would return. Accordingly, when by accident I saw her some months afterwards, she was in a workhouse, and had a large and firm painful tumour in her breast, which, I believe, would have been removed, but that its nature was obscure, and her general health was not good. Again, some months afterwards, she became my patient at the Finsbury Dispensary: her health was much improved, but the hard lump in her breast existed still, as large as an egg, and just like a portion of indurated mammary gland. Having heard all the account of it, and how her mind constantly dwelt in fear of cancer, I made bold to assure her, by all that was certain, that the cancer, as she supposed it, would go away; and it did become very much smaller, without any help from medicine. As it had come under the influ-

ence of fear, so it very nearly disappeared under that of confidence. But I lost sight of her before the removal of the tumour was complete.

The other classes of cases are those in which the influence of the nervous system alone, independent of the Mind, is shown. Of course, such cases can only be drawn from those of abstraction or perversion of the nervous influence; and the effects of these are most plainly expressed in the nutrition of parts exposed to external agencies, as the integuments generally, the extremities, and other external parts: but we may fully believe, that what is observed in these, occurs also, in corresponding measure, in more deeply-seated parts.

Now, for the results of the abstraction or diminution of nervous force, I cite the following from among many similar facts:—In the Museum of St. Bartholomew's (Ser. 9, No. 9) is an example of central penetrating ulceration of the cornea, in consequence of destruction of the trunk of the trigeminal nerve, by the pressure of a tumour near the pons.* The whole nutrition of the corresponding side of the face was impaired; the patient had repeated attacks of erysipelatous inflammation, bleeding from the nose, and, at length, destructive inflammation of the tunics of the eye, and this ulceration of the cornea.

In the College-Museum (No. 2177) is the hand of a man, whose case is related by Mr. Swan, the donor of the preparation. The median nerve, where it passes under the annular ligament, is enlarged, with adhesion to all the adjacent tissues, and induration of both it and them. A cord had been drawn very tight round this man's wrist seven years before the amputation of the arm. At this time, it is probable, the median and other nerves suffered injury; for he

* The case is related by Mr. Stanley in the Medical Gazette, Vol. i. 531.

had constant pain in the hand after the accident, impairment of the touch, contraction of the fingers, and (which bears most on the present question) constantly repeated ulcerations at the back of the hand.

Mr. Hilton has told me this case :—A man was at Guy's Hospital, who, in consequence of a fracture at the lower end of the radius, repaired by an excessive quantity of new bone, suffered compression of the median nerve. He had ulceration of the thumb, and fore and middle fingers, which resisted various treatment, and was cured only by so binding the wrist that, the parts on the palmar aspect being relaxed, the pressure on the nerve was removed. So long as this was done, the ulcers became and remained well ; but as soon as the man was allowed to use his hand, the pressure on the nerves was renewed, and the ulceration of the parts supplied by them returned.

Mr. Travers* mentions a case in which a man had paraplegia after fracture of the lumbar vertebræ. He fractured at the same time his humerus and his tibia. The former, in due time, united : the latter did not.

Mr. De Morgan† has related a similar case. A man fractured his twelfth dorsal vertebra, and crushed the cord ; dislocated his left humerus, and fractured fourteen ribs and his left ancle. He lived eighteen days, during which the reparative process was active at the injuries above the damage of the cord, but seemed to be wholly wanting at those below it.

Sir B. C. Brodie mentions having seen mortification of the ankle begin within twenty-four hours after an injury of the spine.‡

* Further Inquiry concerning Constitutional Irritation, p. 436.

† London Medical and Surgical Journal, Jan. 4, 1834.

‡ Lectures on Pathology and Surgery, p. 309.

It would be easy to multiply facts of this kind, without adducing instances of experiments on lower animals, which, though they be corroborative, cannot be fairly applied here. I will only refer in general to the numerous recorded examples of the little power which paralysed parts have of resisting the influence of heat; of the sloughing after injury of the spinal cord; of the slower repair and reproduction of parts whose nerves are paralysed or divided; all which facts alike contribute to prove, that the integrity of the nervous centres and trunks which are in anatomical relation with a part, is essential to its due nutrition, or, to its capacity of maintaining itself against the influence of external forces, which capacity is itself an expression of the formative power.

Lastly, for cases illustrating the effects produced in nutrition by disturbances of the nervous force, I must refer to the Lectures on Inflammation. At present, I can only allude to the cases of inflammation of the conjunctiva excited by stimulus of the retina; of inflammation of the testicle in consequence of mechanical irritation of the urethra; of the vascular congestion which is instantly produced around a killed or intensely irritated part, or in and around a part in which paroxysms of neuralgia are felt; of the inflammations whose range seems to be determined by the course or distribution of nerves, as in Herpes Zona. In all these cases, I know no explanation for the disturbance of nutrition, except that it is the consequence of the nervous force in the part being directly, or by reflection, disturbed.

The value of all these facts is strengthened by the consideration of the manifold and distinct influences of the nervous force upon secretion; for the process of secretion is so essentially similar to that of nutrition, that whatever can be proved of the method of one might be inferred for that

of the other. And I think the proof of the direct influence of the nervous force upon the formative process would be thus beyond question, if it were not for the inconstancy of the results of injury of the spinal cord and nerves. Even in the warm-blooded animals the division of the cord does not always retard the healing of injuries in the paralysed limbs; sometimes it scarcely affects any part of their nutrition; and even in man, healing may be effected in paralysed limbs after injuries, though they be produced by such trivial causes as would not have disturbed the nutrition of sound limbs. I remember a man with nearly complete paraplegia and distorted feet, the consequence of injuries of the spine, in whom some tendons were subcutaneously divided, and appeared to be healing; but a bandage being applied rather tightly, sloughing ensued at the insteps, on which the chief pressure fell, and extended widely and deeply to the ankle-joints. Both the dorsal arteries were laid open when the sloughs separated, and both the ankle-joints, and the case presented a most striking example of the defective self-maintenance of paralysed parts. But granulations formed after the separation of the sloughs, and the healing process went on slowly, but uninterruptedly, till all was covered-in with a well-formed scar. In another case, a girl, with softening of the brain, had sloughs on nearly every part of the body that was subject to even slight pressure: for instance, on the back of her head resting on the pillow, on her elbows and heels; and yet, while several of these sloughs were extending with fearful rapidity, an ulcer, which had remained after the separation of a slough over the patella, healed perfectly.

Such cases as these seem incongruous in their several parts, and irreconcilable with the general rules which I previously illustrated: I cannot attempt to explain them;

but neither can I think that they materially invalidate the rule.

Let me add, further, that no tissue seems to be wholly exempt from the influence of the nervous force on its nutrition. In the cuticle it is manifest; and, for its influence in acting even through a considerable distance, I may mention a case, which is also in near relation to those in which the hair grows quickly grey in mental anguish. A lady, who is subject to attacks of what are called nervous headaches, always finds in the morning after such an one, that some patches of her hair are white, as if powdered with starch. The change is effected in a night, and in a few days after, the hairs gradually regain their dark brownish colour.

If, now, we may hold this influence of the nervous system to be proved, we may consider the question,—through what class of nerves is the nutritive process influenced?

Indirectly, it is certain that the motor or centrifugal nerves may influence it; for when these are paralysed, the muscles they supply will be inactive, and atrophy will ensue, first, in these muscles: then, in the bones, (if a limb be the seat of the paralysis,) for the bones, in their nutrition, observe the example of their muscles: and, finally, the want of energy in the circulation, which is in some measure dependent on muscular action, will bring about the atrophy of the other tissues of the part. Hence, after a time, the evidences of paralysis of the facial nerve may be observed in nearly all the tissues of the face.

But the effects of destruction of the trigeminal nerve, while the motor nerves of the parts which it supplies are unimpaired, prove that a more direct influence is exercised through sensitive or sympathetic nerves. The olfactory, optic, third, fourth, sixth, and facial nerves, may be one and

all destroyed, yet no disturbance of the nutrition of the nose or eye may ensue. After destruction of the facial, indeed, there may be inflammation of the eye from irritants, which the paralysed orbicularis palpebrarum cannot shut out or help to remove; but neither this nor any other injury of these nerves is comparable with the consequences of the destruction of the trigeminal: consequences which in the rabbit are manifest, and may be very grave, within a day of the destruction of the nerve, and may be completely destructive of the eye within three days.

In many of these cases it is difficult to say whether the influence on nutrition is exercised through sensitive nerve-fibres of the cerebro-spinal system, or through sympathetic (ganglionic) nerve-fibres; and I think it is probable that it may be exercised through either.

On the one side we have the fact that the destruction of the eye ensues more quickly after division of the trigeminal nerve in front of the Casserian ganglion, than when the division is made between the ganglion and the brain. This may imply that filaments derived from the ganglion, or passing through it from the sympathetic nerve, are those through which the influence on nutrition is exercised. And their sufficiency is supported by the fact that great disturbance in the nutrition of the eye is an ordinary consequence of the extirpation of the superior cervical ganglion of the sympathetic, even when the trigeminal nerve is unaffected.

But, on the other side, we have the facts of the destruction of the eye when the trigeminal nerve is spoiled near its origin, the sympathetic nerve being sound (as in the case by Mr. Stanley); and of the defective nutrition in consequence of injuries of the spinal cord, when also the sympathetic centres are uninjured; as in the cases by Sir B. C. Brodie and Mr. Travers. For this view, also, is the

occurrence of general atrophy in consequences of diseases of the brain.

Finally, when defective nutrition follows injury of the spinal cord, it appears to be, directly, due to the injury of the sensitive, rather than the motor, nerve-fibres. Sloughing of the bladder and other parts occurs, I believe, in such cases earlier and more extensively when sensation, than when motion alone, is lost. And Mr. Curling has recorded this case* :—Two men were, at nearly the same time, taken to the London Hospital with injury of the spine; one had lost only the power of motion in the lower extremities; the other had lost both motion and sensation; and at the end of four months the atrophy of the lower extremities in this last was far more advanced than in the first.

None of these cases, however, enable us to say whether the influence on nutrition is exercised through sensitive fibres of the cranio-spinal system, or through sympathetic fibres; nor do I think this question can be yet determined.

The last condition which I mentioned as essential to healthy nutrition, is a healthy state of, the part to be nourished.

This is, indeed, involved in the very idea of the assimilation which is accomplished in the formative process, wherein the materials are supposed to be made like to the structures among which they are deposited: for unless the type be good, the anti-type cannot be.

In a part which was originally well-formed, and with which the three conditions of nutrition already illustrated have been always present, this fourth condition will pro-

* *Medico-Chir. Trans.* Vol. xx. p. 342.

bably be never wanting; for the part will not of itself deflect from the normal state. But when any part, or any constituent of the blood, has been injured or diseased, its unhealthy state will interfere with its nutrition long after the immediate effects of the injury or disease have passed away. Just as, in healthy parts, the formative process exactly assimilates the new materials to the old, so does it in diseased parts: the new-formed blood and tissues take the likeness of the old ones in all their peculiarities whether normal or abnormal; and hence the healthy state of the part to be nourished may be said to be essential to the healthy process of nutrition.

The exactness of assimilation accomplished by the formative process in healthy parts has been already, in some measure, illustrated, as preserving through life certain characteristic differences, even in the several parts of one organ; preserving, also, all those peculiarities of structure and of action, which form the proper features, and indicate the temperament, of the individual. In these, and in a thousand similar instances, the precision of assimilation in the formative process is perfect and absolute, except in so far as it admits of a very gradual alteration of the parts, in conformity with the law of change in advancing years.

Nor is there less of exactness in the assimilation of which a part that has been diseased is the seat. For, after any injury or disease, by which the structure of a part is impaired, we find the altered structure,—whether an induration, a cicatrix, or any other,—as it were, perpetuated by assimilation. It is not that an unhealthy process continues: the result is due to the process of exact assimilation operating in a part of which the structure has been changed: the same process which once preserved the healthy state, maintains now the diseased one. Thus, a scar or a diseased spot may grow and assimilate as its healthy neighbours do. The

scar of the child, when once completely formed, commonly grows as the body does, at the same rate, and according to the same general rule ; so that a scar which the child might have said was as long as his own fore-finger, will still be as long as his fore-finger when he grows to be a man.

Yet, though this increase and persistence of the morbid structure be the general and larger rule, another within it is to be remembered ; namely, that in these structures there is usually (especially in youth) a tendency towards the healthy state. Hence, cicatrices, after long endurance, and even much increase, may, as it is said, wear out ; and thickenings and indurations of parts may give way, and all become again pliant and elastic.

The maintenance of morbid structures is so familiar a fact, that not only its wonder, but its significance, seem to be too much overlooked. What we see in scars and thickenings of parts appears to be only an example of a very large class of cases ; for this exactness by which the formative process in a part maintains the change once produced by disease, offers a reasonable explanation of the fact that certain diseases usually occur only once in the same body. The poison of small-pox, or of scarlet-fever, being, for example, once inserted, soon, by multiplication or otherwise, affects the whole of the blood ; alters its whole composition : the disease, in a definite form and order, pursues its course ; and, finally, the blood recovers, to all appearance, its former state. Yet it is not as it was : for now the same material, the same variolous poison, will not produce the same effect upon it ; and the alteration thus made in the blood or the tissues is made once for all : for, commonly, through all after-life, the formative process assimilates, and never deviates from, the altered type, but reproduces materials exactly like those altered by the disease ; the new ones, therefore, like the old, are incapable of alteration by the

same poison, and the individual is safe from the danger of infection.

So it must be, I think, with all diseases which, as a general rule, attack the body only once. The most remarkable instance, perhaps, is that of the vaccine virus. Inserted once in almost infinitely small quantity: yet, by multiplying itself, or otherwise, affecting all the blood, it may alter it once for all. For, unsearchable as the changes it affects may be; inconceivably minute as the difference must be between the blood before, and the blood after, vaccination; yet, in some instances, that difference is perpetuated; in nearly all it is long retained; by assimilation, the altered model is precisely imitated, and all the blood thereafter formed is insusceptible of the action of the vaccine matter.

In another set of diseases we see an opposite, yet not a contradictory, result. In these, a part once diseased is, more than it was before, liable to be affected by the same disease; and the liability to recurrence of the disease becomes greater every time, although in the intervals between the successive attacks the part may have appeared quite healthy. Such is the case with gout, with common inflammation of a part, as the eye, and many others, in which people become, as they say, every year more and more subject to the disease.

I do not pretend to determine the essential difference between the two classes of disease in these respects, in which they are antipodal; but in reference to the physiology of the formative process, they both prove the same thing, viz. that an alteration once produced in a tissue, whether by external influence, or by morbid material in the blood, is likely to be perpetuated by the exactness of assimilation observed in the formative process, *i. e.* by the constant reproduction of parts in every respect precisely like their immediate predecessors,

But it will be said, the rule fails in every case (and they are not rare) in which a disease that usually occurs but once in the same body, occurs twice or more ; and in every case of the second class in which liability to disease is overcome. Nay, but these are examples of the operation of that inner, yet, not less certain, law,—that after a part has been changed by disease, it tends, naturally, to regain a perfect state. Most often the complete return is not effected ; but sometimes it is, and the part, at length, becomes what it would have been if disease had never changed it.

I will here refer again to what was said in the first lecture concerning the blood's own assimilative power. After the vaccine and other infectious or inoculable diseases, it is, most probably, not the tissues alone, but the blood as much or much more than they, in which the altered state is maintained ; and in many cases it would seem that, whatever materials are added to the blood, the stamp once impressed by one of these specific diseases is retained ; the blood, by its own formative power, exactly assimilating to itself, its altered self, the materials derived from the food.

And this, surely, must be the explanation of many of the most inveterate diseases ; that they persist because of the assimilative formation of the blood. Syphilis, lepra, eczema, gout, and many more, seem thus to be perpetuated : in some form or other, and in every varying quantity, whether it manifests itself externally or not, the material they depend on is still in the blood ; because the blood constantly makes it afresh out of the materials that are added to it, let those materials be almost what they may. The tissues once affected may (and often do) in these cases recover ; they may have gained their right or perfect composition ; but the blood, by assimilation, still retains its taint, though it may have in it not one of the particles on which the taint first passed : and, hence, after many years

of seeming health, the disease may break out again from the blood, and affect a part which was never before diseased. And this appears to be the natural course of these diseases, unless the morbid material be (as we may suppose) decomposed by some specific; or be excreted in the gradual tendency of the blood (like the tissues) to regain a normal state; or, finally, be, if I may so speak, starved by the abstraction from the food of all such things as it can possibly be made from.

In all these things, as in the phenomena of symmetrical disease, we have proofs of the surpassing precision of the formative process, a precision so exact that, as we may say, a mark once made upon a particle of blood, or tissue, is not for years effaced from its successors. And this seems to be a truth of widest application; and I can hardly doubt that herein is the solution of what has been made a hindrance to the reception of the whole truth concerning the connection of an immaterial Mind with the brain. When the brain is said to be essential, as the organ or instrument of the Mind in its relations with the external world, not only to the perception of sensations, but to the subsequent intellectual acts, and, especially, to the memory of things which have been the objects of sense,—it is asked, how can the brain be the organ of memory when you suppose its substance to be ever changing? or, how is it that your assumed nutritive change of all the particles of the brain is not as destructive of all memory and knowledge of sensuous things as the sudden destruction by some great injury is? The answer is,—because of the exactness of assimilation accomplished in the formative process: the effect once produced by an impression upon the brain, whether in perception or in intellectual act, is fixed and there retained; because the part, be it what it may, which has been thereby changed, is exactly represented in the part which, in the course of nutrition,

succeeds to it. Thus, in the recollection of sensuous things, the Mind refers to a brain, in which are retained the effects, or, rather, the likenesses, of changes that past impressions and intellectual acts had made. As, in some way passing far our knowledge, the Mind perceived, and took cognizance of, the change made by the first impression of an object acting through the sense-organs on the brain; so afterwards, it perceives and recognizes the likeness of that change in the parts inserted in the process of nutrition.

Yet here also the tendency to revert to the former condition, or to change with advancing years, may interfere. The impress may be gradually lost or superseded, and the Mind, in its own immortal nature unchanged, and immutable by anything of earth, no longer finds in the brain the traces of the past.

LECTURE III.

THE FORMATIVE PROCESS : GROWTH.

HAVING now considered the sources of the impairment to which the completely formed blood and tissues are prone, and the chief conditions necessary for the perfection of the formative process by which, notwithstanding this impairment, they are maintained almost unchanged, I propose to speak of the process itself.

You may remember that I referred the impairment, or wear and tear, of the body to two principal sources—namely, the deterioration which every part suffers in the exercise of its function; and the natural degeneration or death to which every part is subject after a certain period of existence, independently of the death or degeneration of the whole body, and, in some measure, independently of the exercise of function.

The first question, therefore, in the consideration of the nutritive process, may be,—what becomes of the old particle, the one for the replacement of which the process of formation is required? In answer, we must, probably, draw a distinction, though we can hardly define it, between the parts which die, and those which only degenerate, when they have finished their course. Those which die are cast out entire: those which degenerate are disintegrated or dissolved, and absorbed. We seem to have a good example of this difference in the fangs of the two

sets of teeth. Those of the deciduous ones degenerate, are transformed so as to become soluble, and are absorbed; those of what are called permanent,—more properly, those of teeth which are not to be succeeded by others deriving germs from themselves—die, and are cast out entire. And we may probably hold it as generally true, that, as Mr. Hunter was aware, living parts alone are absorbed in the tissues: dead parts, it is most probable, however small, are usually separated and cast out; and, as the phenomena of necrosis show, this must be accomplished, not by the absorption of the dead parts themselves, or their borders, but by the absorption or retirement of the adjacent borders or surfaces of the living parts.

External, merely integumental, parts appear thus to die, and to be cast out entire from the body; but we have no certain knowledge of the changes they may undergo before they die. And, with regard to the changes which take place in the degeneration that precedes absorption of the old particles, we have, again, but little knowledge. Chemistry has, indeed, revealed much concerning the final disposal of the old materials; finding their elements in the excretions; and proving that the process is one of descent towards simplicity of organic chemical composition; one of approximation towards inorganic character; and, perhaps always, one accomplished by the agency of oxygen. It has, also, we may safely believe, found in the muscles some of the substances into which the natural constituents of the tissues are transformed, before they assume the composition in which they are finally excreted. Kreatine and kreatinine are, most probably, examples of such transitional compounds, intermediate between some of the proper constituents of muscle, and urea or uric acid. And I think that the frequency with which fatty matter is found in degenerate parts is an indication that it is an usual product of

similar transformation, preparatory to absorption, and to the more complete combination with oxygen in the formation of carbonic acid and water for excretion. However, while we have so little knowledge of these intermediate or transitional substances, we can only hold it as generally probable, that the components of the degenerate and out-worn tissues pass through a series of chemical transformations, which begin in their natural degeneration before absorption, and are continued during and after absorption, till they are completed by the oxidation in the blood which brings the materials to the state appropriate for excretion.

With regard to the formative portion of the process,—that by which the old particle, however disposed of, is to be replaced,—it is probably always a process of development; a renewal, for each particle, of the process which was in nearly simultaneous operation for the whole mass in the original development of the tissue. The fibril, for example, which is to be formed anew in a muscle, passes, most probably, through the same stages of development as those did which were first formed in the embryo. We are led to this conclusion, not only by the evident probability of the case, but, first, by the analogy of the hair, the teeth, the epidermis, and all the tissues we can watch; in all, the process of repair or replacement is effected through development of the new parts: and, secondly, by the existence of nuclei or cytoblasts in, I think, all parts which are the seats of active nutrition. For these nuclei (such as are seen so abundantly in strong, active muscles), are not the loitering impotent remnants of the embryonic tissue, but apparatus of power for new formation. Their abundance is, I think, directly proportionate to the activity of growth. They are always abundant in the foetal tissues, and those of the young animal; so they are in many quickly growing tissues; and they are more plentiful in the muscles and the brain than, so

far as I know, any other non-secreting tissue of the adult. It is interesting, too, and significant in this regard, to notice their absence or infrequency in the nerve-fibres of the adult, which in so many points are comparable with the muscular fibres. And I think I may add that their disappearance from a part in which they usually exist is a sure accompaniment and sign of degeneration.

A subject of very interesting inquiry is involved in the difference which we may perceive between what may be called nutritive reproduction and nutritive repetition. I may illustrate my meaning by reference again to the teeth. In our own case, as the deciduous tooth is being developed, a part of its productive capsule is detached, and serves as a germ for the formation of the second tooth; in which second tooth, therefore, the first may be said to be reproduced, in the same sense as that in which we speak of the organs by which new individuals are formed, as the reproductive organs. But in the shark, in which we see row after row of teeth succeeding each other, the row behind is not formed from germs derived from the row before: the front row is simply repeated in the second one, the second in the third, and so on.

It is the same in the blood. The new blood-corpuscles, that are being constantly formed for the renovation of the blood, are not developed from germs given off from the old ones; neither are they formed by any assimilative force exercised by the old ones. By watching the stages of their construction, we may see that the development of each is an independent repetition of the process by which the first were formed. And so with the successive developments of ova and epithelial cells, and many others; each is developed independently of the rest, and each repeats the changes through which its predecessors passed.

Probably we shall find hereafter an analogy in this respect

between tissues and whole animals; and that, as in the latter, the capacity of regeneration of lost parts is in direct proportion to the degree in which the members of the body are only repetitions one of another, so in the tissues, much of the difference in the degree of repair they severally undergo, after injuries or diseases, is connected with the ordinary mode of nutrition by repetition or by reproduction. When the whole cuticle of a part is removed, it may be again formed by repetition; but when a portion of muscle is removed, its germs are taken with it, and it is not reproduced.

Whether by repetition or reproduction, let it be observed that each new elementary structure is made, in successive stages, like what the old one was, not like what it is: as we see in the young hair following the course of the old one, or as the child is made like, not what his father is now, but what he was at his age. The new particle is, therefore, not made after a present model.

If, now, we turn from the consideration of the method of the formative process in the maintenance of the tissues, and from that of the conditions under which it is exercised, to inquire into the nature of the forces which actuate it; if we try to answer why any structure just new-formed has assumed nearly the same form as the old structure had which it replaces; we may find suggestions for an answer in the three classes of facts last mentioned. Among these facts we find (1), as detailed in p. 49, that a structure already formed exercises a certain assimilative influence on organic materials brought into contact or near proximity with it; (2), as in p. 10-11, that, in many cases, certain parts of perfect structures are, as it were, set apart to be or contain the germs of the next succeeding similar structures, so that, in succession as in likeness, the new-formed structure may be called a reproduction of the older; and (3) that in many

cases, as cited in p. 58, and yet more clearly in instances of repair and reproduction of injured and lost parts, the replacing structures are formed entirely anew, and independently of both these conditions. In these cases, no model structure is present to which the new-forming one may be assimilated; no tissue-germ which, by its development, may imitate the structure from which itself was derived; the new structure seems as if its own inherent properties had determined the form that it should take.

Resting on the first two classes of facts, it seems to some a sufficient explanation of the process of maintenance, to say that each structure in the body has the power of taking from the blood, by a kind of elective affinity, certain appropriate materials, and of so influencing them that they assimilate themselves to it; *i. e.* that they adopt or receive its form and properties, and incorporate themselves with it. By others, it is held that each cell or structural element of a part, while developing itself into some higher form, leaves behind or produces tissue-germs, or off-shoots, which, of course, pass through the same development as itself, and in due time succeed to its place and office.

Now, without doubt, the existence of these things is justly assumed, and we may, by reference to them, express correctly a part of the processes by which the maintenance of the body is accomplished. Still it is, I think, clear that they are not sufficient for the maintenance of the body in its perfection. For, in the explanation of all the facts of the third class cited above, a theory of maintenance of the tissues by assimilation, or by the development of successive tissue-germs or cytoblasts, is inapplicable,—not merely insufficient, but inapplicable; for a postulate of this theory is the existence of a present model or germ for the construction of the forming part; and in all these cases no such germ or model can be found. Therefore, finding, in

these cases, that the formative process is accomplished in the maintenance of certain parts, without either assimilation or a succession of germs, we may assume, I think, that even where either of these conditions is present, it is only as an auxiliary of some more constant and sufficient force.

Of this force, by whatever name we designate it, whether as the formative, or the plastic, or, more explicitly, as the force by which organic matter, in appropriate conditions, is shaped and arranged into organic structure; of this force, and of those that co-operate with it, we can, I think, only apprehend that they are, in the completed organism, the same with those which actuated the formation of the original tissues, in the development of the germ and of the embryo. As we have seen that the new formation of elemental structures in the maintenance of tissues is a repetition of the process observed in their first development, so we may assume that the forces operative are the same in both processes.*

* Concerning the very nature of such forces, and their correlations, I must refer to the admirable essays of Mr. Grove (The Correlation of Physical Forces), and Dr. Carpenter (On the Mutual Relations of the Vital and the Physical Forces). "In speaking of *forces* as possessing an absolute existence, it is not intended," says Dr. Carpenter, "on the one hand to imply that they are anything else than 'affections of matter;' nor, on the other, to regard them in any other light than as the direct operation of the Primal All-sustaining Cause. We can form no conception of matter except as possessing *properties*, which, when in action, give rise to *powers* or *forces*; whilst on the other hand, we cannot think of forces, except as operating through some form of matter, of whose properties they are the manifestation. The existence of matter, and the action of the forces to which material phenomena (whether physical or vital) are attributable, are alike the expressions of the Divine Will; and our aim must be limited to the discovery of the plan, according to which it has pleased the Creator to develop and maintain the existing condition of the universe we inhabit."—(General Physiology, p. 36.)

Thus, then, for explanation of the maintenance of tissues by the constant formation of nearly similar elemental structures, we are referred back to the history of their first formation : and we might be content to rest in the belief that the mystery of the development of a germ is wholly inscrutable. We can discern in its method only this ; that the materials of which the impregnated germ first consists, and all that it appropriates, are developed according to the same method as was observed in its progenitors, so that at every stage it is like what they were at the same stage. It is in conformity with the same law of formation according to the example of progenitors, that when the general development of the body is completed, each of its parts is still maintained or gradually changed. In each period of life, the offspring resembles the parents at the corresponding periods of their life ; and, especially, in those degenerative changes which ensue in old age, we can discern no other method, or law, than still the same ; that the parental form, and properties, and life, are imitated or reproduced in the offspring.

Now, can we trace anything further back than this fact ? Probably not : but we may express it in other terms, which may be more conveniently used in our further enquiries, by saying that each germ derives from its parents such material properties that, being placed in the conditions necessary for the operation of the formative and other vital forces, it will imitate in all the phases of the life of each of its parts, the changes through which the corresponding parts passed in the parents. It is convenient, and probably right, while we assume the operation of a formative force, still to refer the method of its peculiar manifestations to the material properties of the substances in which it acts. In the case before us, we may accordingly assume, that peculiar and typical properties are transmitted from its parents to the materials

of each impregnated germ ; that these determine, under the operation of the formative force, the construction of corresponding peculiar and typical forms ; that they are also communicated to whatever materials capable of organisation are brought within the sphere of the developing germ, so that these also determine the same, or some definitely related, method of construction ; and that thenceforward, throughout life, by similar communication or induction of specific properties in the forming blood or other nutritive fluid, the same method of formation is maintained in all the tissues.

Unless we thus assume a dependence of form upon composition, of organic structure upon organic constitution, I think we cannot understand, or even clearly speak of, many of the deflections from the normal formative process which are due to injury or disease: deflections which, as we have seen, are maintained in the blood and tissues, and the tendency to which is, in hereditary diseases, transmitted from parent to offspring with the other properties of the germ.

The sum, then, of the hypothesis concerning the formative processes in the maintenance of the tissues is as follows :—It is assumed, first, that a certain vital formative, or plastic, or constructing force, is in constant operation ; 2dly, that the forms assumed, under its influence, depend primarily, and in greatest measure, on the specific composition and other properties of the organizable materials taken from the blood ; and, 3rdly, that these properties, transmitted in the first instance from the parent to the germ, are thenceforward communicated to all the nutritive materials ; subject, however, to certain progressive changes corresponding to the development and degenerations of the several tissues.

It is assumed, further, that the taking of materials from

the blood, by each part for its own maintenance, depends, as to quality, on certain definite relations, or "organic affinities" between the blood and the part; and as to quantity, on the waste of the part. As to the influence of an assimilative force, exercised by the tissues already formed, upon the nutritive materials placed in them, it is probable that this is not a plastic or constructive force, but chiefly such an one as, like the assumed catalytic force, or that of a ferment, affects first the composition of the materials not yet organized, and thus indirectly affects the form that they assume in organizing.

I fear I may have seemed to have engaged in a very useless discussion, and to have been talking of words more than of things; but the charge will not be made by one who knows the utility of being clear in the expressions used for the ground-work of teaching; or who will consider the importance in pathology of the principle that specific organic structures correspond with, and are determined by, specific organic compositions.

I propose now to consider, but as yet only generally, the second method of the formative process, Growth, in health and in disease.

It consists in the increase of a part, or of the whole body, by addition of new material like that already existing. The essential characters of each organ or tissue are maintained, but its quantity is increased, and thus it is enabled to discharge more of its usual function.

For a general expression of the course of events, we may say that the development and the growth of the body go on together till all the natural structures are attained; and that then, development ceases, and growth goes on alone, till the full stature, and the full proportion of each part to the rest, are gained. But this is only generally true; for we cannot

say that all development ceases at a determinate period, since some organs may go on to be developed when many others are complete. Neither can we assign the period of terminated growth; since, not only is the period, even stated generally, very various in different persons, but, some parts, unless placed in unfavourable conditions of disease, continue growing to the latest period of life. M. Bizot and Dr. Clendinning have proved, of the heart and arteries, that their average size regularly increases, though with a decreasing ratio of increase, from childhood to old age, provided only the old age be a lusty one.* And this is a real growth; for the heart not only enlarges with advancing years, but its weight augments, and the thickness of its walls increases; so that we may believe it acquires power in the same proportion as it acquires bulk—the more readily, since the increased power is necessary for the increasing difficulties put in the way of the circulation by the increasing rigidity of the parts.

It may be that the same is true of some other parts. This certainly is true—that any part, after it has attained its ordinary dimensions, according to the time of life, may grow larger if it be more exercised: in other words, every part has, throughout life, the power of growing, according to its particular needs, in correspondence with the degree in which its function is discharged.

Now, when such growth as this is the result of the natural, though almost excessive, exercise of a part (as of the limbs, for example, during hard work), we regard it only as an indication of health, and its result is admitted to be a desirable accession of strength. But, when such growth in one part is the consequence of disease in another, it is

* Croonian Lectures by Dr. Clendinning, *Medical Gazette* for 1837-8, vol. xxii. p. 450.

commonly described as a disease; it bears the alarming name of Hypertrophy; and it comes to be a subject of consideration in Morbid Anatomy.

But in both these cases the process of growth is the same, and is according to the same rules; and the tendency of the process of genuine hypertrophy in disease, like that of healthy growth in active exercise, is always conservative. I say genuine hypertrophy, meaning, under that term, to include only the cases in which the enlargement of a part is effected with development or increase of its natural tissue, with retention of its natural form, and with increase of power. To include all enlargements under the name of hypertrophy is too apt to lead to misunderstanding.

The rule, then, concerning hypertrophy is, that so long as all conditions remain the same, each part of the body after the attainment of the average size, merely retains its state, or, at most, grows at a certain determinate slow rate; but when the conditions alter, so that a part is more than usually exercised in its office, then it manifests a power of renewing or accelerating its growth. It is as if each healthy part had a reserve-power of growth and development, which it puts forth in the time of emergency. And the converse is equally true: when a part is less than usually exercised, it suffers atrophy; so that the rule may be that each part nourishes itself according to the amount of function which it discharges.

We may constantly see this rule in many more examples than I need refer to. The simplest case that can be cited is that of the epidermis. In its original formation, even before it has come into relation with the external world, it is formed on the several parts of the body—take, for example, the back and the palm of the hand—in different quantity and kind, adapted to the several degrees in which the cutis it is to protect will be exposed to pressure, friction, and the

influence of other external forces. And, not only are its original quantity and construction on these parts different, but its rate of growth is so; for, though the back of the hand loses comparatively little by friction or otherwise, yet its epidermis does not grow thick; and though the palm loses more, yet its epidermis does not grow thin. So, then, both in original construction, and in rate of formation, the epidermis is thus adapted to the amount of function it has to discharge; that is, to the amount of protection it has to afford. But suppose now, that, by some new handicraft, the amount of exercise of the epidermis is increased; its rate of waste is increased in the same proportion, yet it does not grow thin; nay, it grows thicker, till it is completely adapted to protect the cutis from the greater sources of injury to which it is now exposed: it puts forth, as it were, a reserve-power, which is enough not only to repair all amount of waste within certain limits, but, further than this, to increase the quantity of the tissue to the amount required for the discharge of its increased functions.

What we can see in this case of the cuticle, we may be sure of for other tissues: for example, in a muscle; as in a heart, when, by disease of the valves, an obstacle is put in the way of the circulating blood, and the heart, or one of its cavities, acts with additional force to drive it on. But, as we know, the more of action in a muscle, the more the consumption of the tissue, so we might now expect a diminution of the heart. On the contrary, it enlarges; it is hypertrophied; the formative process not only meets the immediate exigencies of the increased consumption of muscular tissue, but produces enough to act with the additional power required by the increased difficulty of the circulation.

Such are the effects of growth in examples of hypertrophy. But, to meet the increasing difficulties of these and the like

cases, a part may do more than grow ; it may develop itself ; it may acquire new structures, or it may improve those of which it is already composed, so as to become fit for higher functions and the exercise of greater power. For example, in the most ordinary hypertrophy of the heart, the muscular tissue is developed to more robustness : its fibres become not only larger, or more numerous, but firmer, more highly coloured, and stronger. In the pregnant uterus, such fibres are formed as are not seen in the unimpregnated state ; they are, indeed, not a new kind of fibre, but they are so different in size and shape, and so much more powerful than those which existed before, that we may justly speak of them as developed. And this change by development, which in pregnancy is natural, is often imitated in disease, when, by the growth of fibrous tumours in it, the uterus attains the size, the structure, and even the full capacity of action, of the pregnant organ. In several of such cases the uterus has at length imitated the course of labour, and delivered itself of the tumour by its contractile power.

A similar change, by development and growth of muscular fibres, may occur in the gall-bladder, the ureter, and, probably, in any other part that has the smooth muscular fibro-cells.

We have an example of development of a secreting structure in the bursa, which, as Hunter displayed it, is produced under a corn. The corn itself is the result of a kind of hypertrophy, tending to shield the cutis from unnatural pressure ; but, itself becoming a source of greater trouble than that against which it was directed, it gives rise to the development of a bursa beneath it, which may, for a time, more effectually protect the joint beneath, by diffusing the pressure over a wider extent of surface.

All these are examples that this hypertrophy, as we call

it, though it happens in circumstances of disease, is yet in general, so far as itself is concerned, a process of full and vigorous health, serving to remedy or keep back the ill effects that would ensue from disease in some other part. It is, in a less degree than the repair of a fracture or other mechanical injury, an instance of the truth that we are provided for accidents and emergencies ; framed not merely to live in peace and sameness, but to bear disturbances ; to meet, and balance, and resist them, and, sometimes at least, to counteract them.

The amplified healthiness of the formative process exercised in hypertrophy is testified by its requiring a full measure of all the conditions of ordinary nutrition. It needs healthy and appropriate blood : and one of the most interesting studies is to watch the hindering influence of disease on the occurrence and progress of hypertrophy, especially that of the heart. In some of these cases, to which I shall have again to refer, death seems clearly to be the consequence of impairment of the blood, which can no longer maintain in the heart the exceeding growth required for its increased functions.

We find, moreover, very constantly, that, as if to insure sufficient blood to the grown or growing part, the main arteries and veins belonging to it are enlarged. This is usually well shown in the enlarged coronary arteries of the hypertrophied heart ; an instance analogous to the enlargement of the arteries of the pregnant uterus, and the growing antlers of the deer, and many others. According to all analogy, we must consider this increase of the blood-vessels to be secondary. As in the embryo, parts form without vessels, till, for their further nutrition as their structure becomes more complex, the passage of blood into their interior becomes necessary, so, we may be sure, it is here. It is, indeed, strange that a part should have the power, as

it seems, of determining in some measure the rate at which blood shall flow into it and through it; but so it is, and nearly all examples of hypertrophy are examples of the fact; though, as I shall presently have to mention, there are instances in which hypertrophy is the consequence, not the cause or precedent, of increased supply of blood.

With the increased supply of blood proportioned to the increased nutrition of the growing part, the nerves may also increase; as in the pregnant uterus and the hypertrophied heart. So, at least, I believe; but probably I need not apologise for evading the discussion of this matter.

The conditions which give rise to hypertrophy are chiefly or only three, namely—

1. The increased exercise of a part in its healthy functions.
2. An increased accumulation in the blood of the particular materials which a part appropriates to its nutrition or in secretion.
3. An increased afflux of healthy blood.

Of hypertrophy as the consequence of the increased exercise of a part, I have already spoken generally; and we need no better examples of it than the muscles of a strong man's arm, fitted for the very exercise in which they acquired bulk and power, or the great robust heart of a man who has suffered some disease producing obstacle to the movement of the blood. Both alike are the results of vigorous healthy growth, brought about by exercise of the part in its proper function.

In a former lecture (page 27) I spoke of the increased growth of the kidney, and of the adipose and other tissues, when the chief constituents of their structures exist in excess in the blood. To these I may refer again as examples of the second kind of hypertrophy. And I just now mentioned, that although in most cases an in-

creased circulation of blood is the consequence of hypertrophy, yet there are cases in which the course of events is inverted. The increased flow of healthy blood through a part, if it be not interfered with by local disease, will give rise to hypertrophy of the part, or, at least, of some of its tissues.

This fact is shown very well in a specimen (No. 6) in the Museum, which Mr. Hunter described as "a sore which had continued inflamed a long time, where the increased action had made the hair grow." The integuments, for about an inch round the ulcer, where probably there was simply increased supply of blood, are covered with thick-set, long, and rather coarse, dark hairs: while on the more distant parts of the integuments, the hair is paler, more slender, and more widely scattered.

Similar examples of overgrowth of the hair through increased supply of blood, assisted probably by more than usual external warmth and moisture, are frequently seen near the ends of stumps which have remained long inflamed, and about old diseased joints; not, indeed, at the very seat of inflammation, but at some little distance from it, where the parts share the increased supply of blood, but not the disease of inflammation. Such cases are often observed on limbs in which fractures have occurred. I remember one very striking case in the thigh of a child about five years old. The femur had been fractured near the middle: the case did not proceed favourably; and union was not accomplished without much distortion. When I saw the child, I was at once struck with a dark appearance on the thigh: it was all covered with dark hair, like that of a strong coarse-skinned man; yet, on the rest of the body, the hair had all the fineness and softness which are proper to it in early life.

Similar facts are presented by some cases of transplantation. When the spur of a cock, for example, is trans-

planted from the leg to the comb, which abounds in blood, its growth is marvellously augmented, and it increases to a long, strange-looking mass of horny matter, such as is shown in two preparations in the Museum of the College. In one (54) the spur has grown in a spiral fashion, till it is six inches long; in the other (52) it is like a horn curved forwards and downwards, and its end needed to be often cut, to enable the bird to bring his beak to the ground in feeding, and to prevent injurious pressure on the side of the neck.

It is worth observing, that these excessive growths have taken place on the combs without any corresponding diminution in the growth of the spurs in their proper places. The legs of these cocks are amply spurred, though the spur reproduced is not so long as that which had not been interfered with. In one instance, moreover, (No. 53,) there is an excessive production of the horny scales upon the legs, while the horny spur was also excessively growing on the comb.

I shall have occasion presently to mention cases which make it very probable that the more complex and vascular tissues, such as the muscles, integuments, and bones of a limb, can be thus hypertrophied by excess of blood. I will now only suggest the probability that the cases of congenital or spontaneous hypertrophy of a hand, or a foot, or of one or more fingers, have their origin in some excessive formation of the vessels, permitting the blood to flow more abundantly through the part. An enlargement of the radial artery has been observed by Dr. John Reid* in a case of such hypertrophy of the thumb and fore-finger; but there is no evidence to determine whether in this case the enlargement of the artery was previous or subsequent to the excessive growth of the part.

* Lond. and Edinb. Monthly Journ. of Medical Science, 1843, and in a collection by Mr. Curling in the Med.-Chir. Trans. vol. xxviii.

Whatever be the case in these instances of enlargement, the fact, which the others show, that well-organized tissue, like hair and horn, is produced in consequence of simply increased supply of blood, stands in interesting contrast with the phenomena of inflammation, where no tissue, or only the most lowly organized, is ever formed. No fact can better shew how far the mere enlargement of the blood-vessels is from constituting the essential part of inflammation.

Through cases of hypertrophy, such as these, the transition is made to those which, though they appear to consist in simple increase of the natural texture of parts, we yet must regard as morbid, while we do not know that they are adapted to any exigency of the economy. Such are the simple enlargements of the thyroid, thymus, and prostate glands, of the spleen, and tonsils: such too are some examples of mucous polypi, and of cutaneous outgrowths, and warty growths of the skin. These all present an increase of natural textures; and they may be instances of purposive growth, adapted and conservative: but till it is more manifest that they are so, we must be content, I think, to regard them as occupying a kind of middle ground between the genuine hypertrophies of which I have been speaking, and the thoroughly morbid outgrowths of which a part of the class of tumours is composed.

On another side, there are cases intermediate between hypertrophies and the results of inflammation, and no line of distinction can be drawn among them, if we rely on their anatomical characters alone; for, in the lowest degrees of inflammation, the exuded material may be organized into a very near likeness to the natural tissues, and may thus seem to increase their quantity. If these inflammatory hypertrophies, as they have been called, can be distinguished from true ones, it is only by their being unattended with increase of functional power, or fitness for the part's relations.

LECTURE IV.

HYPERTROPHY.

LET me now further illustrate the general physiology of Hypertrophy, by adducing some of the specimens in the Museum which exhibit it in the principal tissues.

The first specimen in the Pathological division of the Museum is an urinary bladder hypertrophied in consequence of stricture of the urethra. It affords an admirable instance of genuine unmixed hypertrophy; for every part of the bladder is grown large; it is not contracted as if it had been morbidly irritable; and its mucous membrane, without induration or any similar morbid change, is increased, apparently by simple growth, to a thickness proportionate to that of the muscular coat.

I adduce this especially as an example of hypertrophy of muscular tissue, concerning which, instead of adding to what was said in the last lecture, I will quote Mr. Hunter's account. Referring, perhaps, to this very specimen, he says, in a passage which I have inserted in the Catalogue:* "The bladder, in such cases [of obstruction to the passage of urine], having more to do than common, is almost in a constant state of irritation and action; by which, according to a property in all muscles, it becomes stronger and stronger in its muscular coats; and I suspect

* Vol. i. p. 3; and Hunter's Works, ii. 299.

that this disposition to become stronger from repeated action is greater in the involuntary muscles than the voluntary; and the reason why it should be so is, I think, very evident: for, in the involuntary muscles, the power should be in all cases capable of overcoming the resistance, as the power is always performing some natural and necessary action; for whenever a disease produces an uncommon resistance in the involuntary parts, if the power is not proportionally increased, the disease becomes very formidable; whereas in the voluntary muscles there is not that necessity, because the will can stop whenever the muscles cannot follow; and if the will is so diseased as not to stop, the power in voluntary muscles should not increase in proportion."

Nothing, surely, could more appositely, or more exactly, express the truth concerning hypertrophy of muscle; and it may be observed, from what he says in a note, that Mr. Hunter appears to have been the first who rightly apprehended the nature of this growth of the bladder. He says, "This appearance was long supposed to have arisen from a disease of this viscus; but, upon examination, I found that the muscular parts were sound and distinct, that they were only increased in bulk in proportion to the power they had to exert, and that it was not a consequence of inflammation, for in that case parts are blended into one indistinct mass."

What this specimen shows in the urinary bladder is an example of the change which ensues in all involuntary muscles under the same circumstances. They all grow and acquire strength adapted to the new and extraordinary emergencies of their case. Thus, the œsophagus, the stomach, the intestinal canal, as often as any portion is the seat of stricture, display hypertrophy of the muscular coat above the stricture. The enormous enlargements of the

intestinal canal, which gradually ensue above nearly impassable strictures of the rectum, are not mere dilatations, but growths of the intestinal walls; the muscular coat augmenting in power, to overcome, if it may, the increased hindrance to the propulsion of the contents, and even the glands and other textures of the mucous membrane simultaneously increasing.

In a great majority of cases, the hypertrophy of muscles, whether voluntary or involuntary, is the consequence of an increased obstacle to their ordinary action. Against this obstacle they exert extraordinary force, and this induces, indirectly, extraordinary formation of their tissue. Frequent action of muscles, unless it be also forcible, does not produce hypertrophy. As Mr. Humphry* says, the heart, though it may act with unusual frequency for years, yet does not in these cases grow larger; and the muscles of the hands are not generally so large in mechanics who use great celerity of action, as in those who work with great force. But action of muscles, if it be at once frequent and forcible, may produce hypertrophy, even though the action be unhealthy. This appears to be the case with the bladders of some children, who suffer with frequent and very painful micturition, and nearly all the signs of calculus, but in whom no calculus exists. The bladder in such children is found, after death, exceedingly hypertrophied, and there may be no other disease whatever of the urinary organs. Dr. Golding Bird has shown that phymosis, by obstructing the free exit of urine, may give rise to these signs and to extreme hypertrophy of the bladder; but in some cases it appears certain that hypertrophy may occur without either phymosis, calculus, stricture, or any

* Lectures on Surgery, in *Prov. Med. and Surg. Journal*; Reprint, p. 108.

similar obstruction. It was so in a case illustrated in the Museum of St. Bartholomew's (xxvii. 14), in a child four years old, who had suffered intensely with signs of stone in the bladder, but in whom no stone existed; no disease of the urinary organs could be found, except this hypertrophy of the muscular coat of the bladder. An exactly similar case has been recently under Mr. Stanley's care, in which, after exceeding irritability of the bladder, the enlargement of its muscular coat appeared the only change.

In such cases, the too frequent and strong action of the bladder, though irritable and unhealthy, seems alone to give rise to hypertrophy of the fibres. It is, however, possible that the change may be due to narrowing of the urethra by muscular action. If, for example, the compressors of the urethra, instead of relaxing when the muscular coat of the bladder and the abdominal muscles are contracting, were to contract with them, the obstacle they would produce in the urethra would soon engender hypertrophy of the bladder.

Hunter, whose ingenuity was ever tempting-on his intellect and industry, asked himself whether the hypertrophy of the heart were accomplished by the addition of new fibres, or by the enlargement of those that already exist. This question could hardly be determined without more microscopic aid than Hunter had at his command. But if we may believe (and there can be no doubt we may) that hypertrophy is, in this respect also, exactly similar to common growth, the question set by Hunter has been answered by Harting,* with whom, on this point, Kölliker† agrees. He has shown that, in the growth of striped muscles, there is no multiplication, no numerical increase,

* Rech. Micrométriques, 1845, p. 62.

† Mikrosk. Anatomie, ii. 255.

of the fibres, but an enlargement of them with addition to the number of the fibrils.

Hypertrophy of bone presents itself in many interesting cases. It is usually a secondary process, ensuing in consequence of change in a part with which some bone is intimately connected. Just as in their natural development and growth, the bones of the skull are formed in adaptation to the brain, and those of the limbs are framed to fitness for the action of the muscles; so, in disease, they submit in their nutrition to adapt themselves to the more active parts. Thus, the skull enlarges when its contents do; and the bones of the limbs strengthen themselves as the muscles inserted on them become stronger and more active; and they do this in adaptation to the force of the muscles, and not merely because of the movements they are subject to: for no extent or force of passive movement would prevent the bones of a limb whose muscles are paralysed from suffering atrophy.

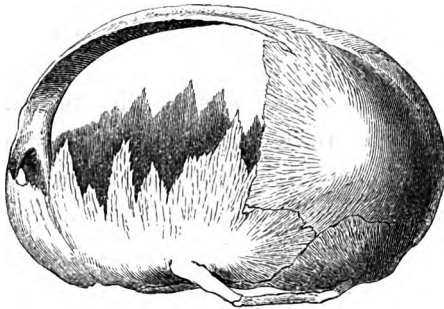
In the skull, if in any organ, we might speak of two forms of hypertrophy; eccentric and concentric. When the cranial contents are enlarged, the skull is hypertrophied with corresponding augmentation of its area; and when the cranial contents are diminished, the skull (at least in many cases) is also hypertrophied, but with concentric growth, and diminution of its capacity.

The first, or eccentric form, is usually the consequence of hydrocephalus; wherein, as the fluid collects and distends the dura mater, so the skull grows; still, as it were, striving to attain its purpose, and form a complete envelope for the expanding brain.

The process of enlargement in these cases is often one of simple growth, and that, indeed, to a less extent than it

may seem at first sight : for it is very rarely that the due thickness of the skull is attained while its bones are engaged in the extension of their superficial area. Hence, the weight of an hydrocephalic skull is not much, if at all, greater than that of a healthy one ; a large parietal bone,* measuring nine inches diagonally, weighs only four ounces, while the weight of an ordinary parietal bone is about three ounces.

FIG. 3.



It is interesting to observe, in some of these cases, the symmetrical placing of the Wormian bones, by which the extent of the skull is in a measure made-up. They show how the formative process, though thus thrown into straits and difficulties, yet conforms, both in growth and development, with the law of symmetry.

It would be yet more interesting if we could certainly trace here something of conformity with the law of unity of organic type, in the mode of insertion of these Wormian intercalary bones, when compared with those of other animals. It cannot be certainly done ; and yet, in some of these specimens, there appears (as if in accordance with

* No. 2 in the College-Museum.

that law) a tendency to the formation of the Wormian bones at the posterior part of the sagittal suture more than in any other part, as if in imitation of the interparietal bones of Rodents. And in the very rare specimen* sketched in the diagram (Fig. 3, p. 79), in the midst of great confusion of the other bones, we find a remarkable bony arch, extending from between the two frontals to the occipital bone; occupying, therefore, the place of a large interparietal bone, and reminding us of some of the monkeys, *e. g.* Cebus and Jacchus. We have a somewhat corroborative specimen in the immense hydrocephalic skull of the skeleton from Mr. Liston's Museum (No. 3489), in which the interparietal Wormian bones are larger than any others.

The hypertrophy of the skull, which may be called concentric, is that which attends atrophy with shrinking of the brain, or, perhaps, any disease of the brain in which there is diminution of its bulk. In such a case it usually happens, as was first shown by Dr. Sims,† that the skull becomes very thick.

All the specimens which I have examined show, however, that in these cases the thickening of the skull is not, in itself, a morbid process; it manifests definite purpose; is usually effected by healthy growth; and observes the rules followed in the natural formation of the skull.

Thus, as in first formation, the skull adapts itself to the form and size of the brain, or, rather, of its membranes; only now it does so without representing on its exterior the change which has taken place within. The thickening of the skull is effected by the gradual remodelling of the inner table and diploe of the bones of the vault; so that, although the exterior of the skull may retain its natural form and size, the

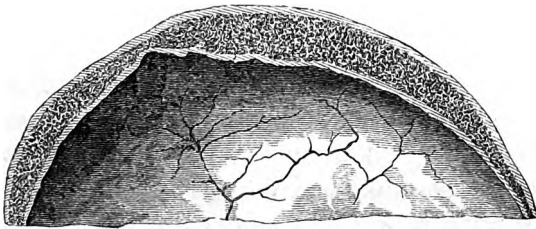
* No. 3487 in the same Museum.

† Medico-Chirurgical Transactions, vol. xix. p. 315.

inner table grows more and more inwards, as if sinking towards the retiring and shrinking brain ; not thickening, but simply removing from the outer table, and leaving a wider space filled with healthy diploe.

Again, it is a fact of singular interest, that this thickening, this hypertrophy of the skull, most commonly, if not always, takes place especially, and to a greater extent than elsewhere, in the parts of the bones in and about which ossification commenced in the foetal state : as if, one might say, some of the potency that of old brought the foetal membrane of these parts first into the development of bone, were always afterwards concentrated in them ; or as if a reserve-power of growth had its seat in the same centres where was formerly the originative power of development. The fact is shown in many cases of the specimens ; especially in one that is represented here (Fig. 4) ; and we may find some

FIG. 4.



further, though less sure, evidence of the peculiar formative energy of these old centres, in the fact that those diseases of bone which are accompanied with excessive formation, such as morbid thickenings of the skull and tumours, are, in a large majority of cases, seated in or near the centres of ossification ; you rarely find them except at the articular ends, or round the middle of the shaft. The same does not hold of necrosis, rickets, ulceration, or other diseases indicative of

depression of the formative power of the bone. Rather, as some specimens (Nos. 390-1-2) of ricketty disease of the skull and femora show, the centres of ossification are remarkably exempt from the change of structure which has extensively affected the later-formed parts.

This peculiarity of the centres of ossification is the more remarkable when we remember that, in many cases, the thickening of the skull takes place in persons far past the middle period of life; it may happen even in very old age, and may give one more evidence of that precision of assimilation which maintains, throughout life, characteristic distinctions among portions of what we call the same tissue.

Let me, however, remark, that it is not peculiar to old persons: I believe that at whatever age, after the complete closure of the cranial sutures, shrinking of the brain may happen, this hypertrophy of the skull may be its consequence. One specimen, for instance (No. 379), is part of the skull of a suicide, only thirty years old: another (No. 380), from an idiotic woman, has not the characters of an old skull. I once examined a remarkable case, showing the same conditions, in a person less than thirty years old, in whom the thickening of the skull must have begun in early life. She was a lady of remarkable personal attractions, but of slenderly developed intellect, whose head did not, externally, appear below the average female size. Yet her cranial cavity was singularly contracted; the skull had adapted itself to an imperfectly-grown brain, by the hypertrophy of its diploe, which was nearly half an inch thick at and near the centres of ossification of the frontal and parietal bones.

Such hypertrophy, however, is not always the mode by which the skull is adapted to the diminished size of the brain. In congenital and very early atrophy of the brain, the skull is proportionally small, and may exactly represent

the size and shape of the cerebrum. It does so in the cases of small-skulled idiots, and in a remarkable skull in the Museum of St. Bartholomew's Hospital. The man from whom this skull was taken received a compound fracture of the left frontal bone when he was only 14 years old. Portions of bone were removed; hernia cerebri ensued, and several pieces of brain were sliced off. But he recovered and lived thirty-three years. The left hemisphere of the cerebrum was altogether small. Where the brain had been sliced off, its surface had sunk in very deep, and had left a cavity filled with a vascular spongy substance containing ill-formed nerve-fibres. You will observe here, that in the modelling of the skull, the left side has become in every part less capacious than the right, adapting itself to the diminished brain without any hypertrophy of the bones.

The cases are very rare in which hypertrophy of any other bones than those of the skull occurs in connection with what is recognised as disease. For, as I have said, the bulk of most of the other bones is principally determined by the activity of the muscles fixed on them; and a morbidly excessive action of muscles, sufficiently continued to produce hypertrophy of bones, is seldom, if ever, met with.

But there is a condition of bones so similar to hypertrophy in many respects, and so little different from it in any, that I may well speak of it here; yet not without acknowledging that nearly all I know about it is derived from Mr. Stanley.

When any of the long bones of a person who has not yet attained full stature is the seat of disease attended with unnatural flow of blood in or near it, it may become longer than the other or more healthy bone. For example, a lad, suppose, has necrosis of the femur, it may be of a small portion of it, and he may recover completely from this dis-

ease ; but for all his life afterwards, (as I had constant opportunity, once, of observing in a near relative), he may be lame, and the character of his lameness will show that the limb which was diseased is now too long ; so that he is obliged, in walking, to lift the lame leg, almost like a hemiplegic man, lest his toe should trip upon the ground.

Such cases are not uncommon : I once saw, with Mr. Stanley, a member of our profession, in whom this elongation of one femur had taken place to such an extent that he was obliged to wear a very high shoe on the other, that is, the healthy, limb. And this, which he had adapted for himself, affords the only remedy for the inequality of limbs. Nor is the remedy unimportant : for, to say nothing of the unsightly lameness which it produces, the morbid elongation of the limb is apt to be soon complicated by one of two serious consequences. Either the patient, in his endeavours to support himself steadily and upright, will acquire first the habit, and then the malformation, of talipes of the healthy limb : or else, through the habit of always resting on the short, healthy, and stronger limb, he will have lateral curvature of the spine. Cases of both these kinds have occurred in Mr. Stanley's practice ; being brought to him for the remedy, not of the elongated femur, but of the consequent deformity of the foot or the spine.

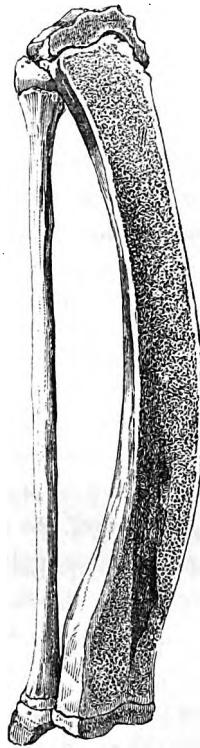
A considerable elongation of the lower extremity almost always depends on the femur being thus affected : another, and very characteristic result, ensues from the same kind of hypertrophy when it occurs in the tibia. The femur can grow longer without materially altering its shape or direction, but the tibia is tied by ligaments at its two ends to the fibula ; so that when it lengthens, unless the fibula should lengthen to the same extent, it, the tibia, must curve ; in no other way, except by the lengthening of the ligaments,

which, I believe, never happens to any considerable extent, is elongation of the tibia possible.

Tibiæ thus curved are far from rare ; specimens are to be found in nearly every museum : yet I know of none in which the pathology of the disease is clearly shown, except one in the Museum of St. Bartholomew's (Subser. A, 46), which is here sketched, Fig. 5. In this, the fibula, and the healthy tibia of the opposite limb, are preserved with the elongated tibia. The anterior wall of this tibia, measuring it over its curve, is more than two inches longer than that of the healthy one : the posterior wall is not quite so long.

In all such specimens you may observe a characteristic form of the curve, and its distinction from the curvature of rickets. The distinction is established by these particulars : the ricketty tibia is always short ; the other is never short, and may be longer than is natural : in the ricketty one the articular ends always enlarge very suddenly, for the shortening is due to the imperfect formation of the ends of the shaft ; in the elongated tibia, there is usually even less contrast of size between the shaft

FIG. 5.



and epiphyses than is natural, because the elongation of the shaft is commonly attended with some increase of its circumference : but, especially, the ricketty tibia is compressed, usually curved inwards, its shaft is flattened laterally, and its margins are narrow and spinous; while, in the elongated tibia, the curve is usually directed forwards, its margins are broad and round, its surfaces are convex, and the compression or flattening, if there be any, is from before backwards.

The elongation of the bones in these cases may occur, in different instances, in two ways. In some cases it seems due to that change in bone which is analogous to chronic inflammation of soft parts, and which consists in the deposit of the products of inflammation in the interstices of the osseous tissue, their accumulation therein, and the remodelling of the bone around them as they accumulate. Such a change appears to have occurred in the specimen from which the sketch was taken, and would necessarily give rise, in a growing bone, as it does in soft parts, to enlargement in every direction, to elongation as well as increase of circumference.

But, in other cases, the elongation is probably due to the more genuine hypertrophy which follows the increased flow of blood. When, for example, a small portion of bone, as in circumscribed necrosis, is actively diseased, all the adjacent part is more vascular; hence may arise a genuine hypertrophy, such as I have shown in hair under similar circumstances. Or, when an ulcer of the integuments has long existed in a young person, the subjacent bone may share in the increased afflux of blood, and may enlarge and elongate. Even, it appears, when one bone is diseased, another in the same limb may thus be increased in length. A remarkable instance of this kind has lately

been observed by Mr. Holden, in a young man, who, in childhood, had necrosis of the left tibia, one of the consequences of which was defective growth of the left leg, with shortening to the extent of more than an inch. Yet the whole limb is not shorter than the other; for, without any apparent morbid change of texture, the femur of the same side has grown so as to compensate for the shortening of the tibia.

An interesting example of similar increased growth of one bone, in compensation for the weakness of another, is found sometimes in cases of ill-repaired fractures or diseases of the tibia. The fibula, at the part corresponding with the weak portion of the tibia, is in such cases strengthened sufficiently for the support of the limb. So in a specimen in the Museum of St. Bartholomew's (Ser. 3; 86), taken from a dog ten weeks after a piece of the radius was cut out with its periosteum, while the gap in the radius is filled with only soft tissue, the exactly corresponding portion of the ulna is increased by the formation of new bone beneath its periosteum.

I must not forget to say, that the interest of these cases of inequality of the limbs, by lengthening of one of the bones, is increased by comparison with another class of cases, in which as great or greater inequality of length depends on one limb being anormally short. In these, the short limb has been the seat of atrophy, through paralysis of the muscles dependent on some of the very numerous conditions in which they may be rendered inactive. The complication of the cases, the talipes, and the curvatures of the spine, depending, as they do, on the inequality of the length of the limbs, from whatever cause arising, will be alike in both; and much care may be needed in diagnosis, to tell which of the limbs, the long one or the short one, is

in error. The best characters probably are, that when a limb is, through disease or atrophy, too short, it will be found, in comparison with the other, defective in circumference as well as in length; its muscles, partaking of the atrophy, will be weak and flabby, and all its tissues will bear signs of imperfect nutrition. If none of these characters be found in the short limb, the long one may be suspected; and this suspicion will be confirmed, if there be found in it the signs of increased nutrition, such as enlargement, growth of hair, and the rest: or if, in the history of the case, there be evidence of a disease attended with an excess in the supply of blood.

Continuing to select from the Museum only such examples of hypertrophy as may illustrate its general pathology, I pass over many, and take next, those which display the formation of corns; a subject which, while Hunter deemed it worth consideration, we shall not be degraded by discussing. He made many preparations of corns, to show not only the thickening of the cuticle, but the formation of the little sac of fluid, or bursa, between the thickened cuticle and the subjacent articulation. His design appears to have been, mainly, to illustrate the different results of pressure; to show how that which is from without produces thickening; that from within, thinning and absorption of parts. He says, having regard to these specimens, "The cuticle admits of being thickened from pressure in all parts of the body: hence we find that on the soles of the feet of those who walk much the cuticle becomes very thick; also on the hands of labouring men. We find this wherever there is pressure, as on the elbow, upper part of the little toe, ball of the great toe, &c. The immediate and first cause of this thickening would appear to be the stimulus of neces-

sity given to the cutis by this pressure, the effect of which is an increase of the cuticle to defend the cutis underneath. Not only the cuticle thickens, but the parts underneath, and a sacculus is often formed at the root of the great toe, between the cutis and ligaments of the joint, arising from the same cause, to guard the ligaments below.”*

In another place he says, “When from without, pressure rather stimulates than irritates; it shall give signs of strength, and produce an increase of thickening: but, when from within, the same quantity of pressure will produce waste” [as illustrated in Nos. 120 and 121 in the Pathological Museum]; “for the first effect of the pressure from without is the disposition to thicken, which is rather an operation of strength; but if it exceeds the stimulus of thickening, then the pressure becomes an irritator, and the power appears to give way to it, and absorption of the parts pressed takes place, so that Nature very readily takes on those steps which are to get rid of an extraneous body, but appears not only not ready to let extraneous bodies enter the body, but endeavours to exclude them by increasing the thickness of the parts.”†

It is evident from these passages that Mr. Hunter was aware that pressure from without might produce atrophy; though he may appear to favour the belief, which, I think, is commonly adopted as on his authority, that the direction of the pressure is that which determines its result. Really, the result seems to depend more on whether the pressure be occasional or constant. Constant extra-pressure on a part always appears to produce atrophy and absorption; occasional pressure may, and usually does, produce hyper-

* Hunter's Works, vol. i. p. 560.

† Ibid. vol. iii. p. 466.

are the consequences of occasional pressure; as the pressure of shoes in occasional walking, of tools occasionally used with the hand, and the like: for it seems a necessary condition for hypertrophy, in most parts, that they should enjoy intervals in which their nutrition may go on actively. But constant pressure, whether from within or from without, always appears to give rise to unrepaired absorption: and most museums contain interesting examples of its effects.

Some vertebræ in the College Museum (121 A.), illustrate very well the results of pressure by aneurisms and tumours. So far as themselves are concerned, the pressure of the aneurism was from without inwards; yet they are atrophied; not ulcerated, but hollowed out, and remodelled in adaptation to the shape of the aneurismal sac: their cancellous tissue is not exposed, but, as in the natural state, is covered by a complete thin external layer of compact tissue.

The pressure of a loose mass of bone in the knee-joint (No. 955 in the same Museum), was from without inwards; but its result was atrophy, as shown in the formation of a deep pit at the lower end of the femur, in which it lay safely and almost tightly lodged.

Again, the effect of constant pressure is shown in the cases in which one of the lower incisor teeth of a rodent animal has continued its growth after the loss of the corresponding upper incisor, and, being no longer worn down by attrition in growing, attains an unnatural length. In such a case, the extremity of the tooth, turning round so as to form nearly a complete circle, has come into contact with the side of the lower jaw, and (like, as they tell, the Fakir's finger-nails growing through the thickness of his clenched hand) it has perforated the whole thickness of

the jaw ; the absorption consequent on its pressure making trophy and thickening. All the thickenings of the cuticle way for its onward course.

A yet stranger example was taken from the body of a woman in the dissecting-room of St. Bartholomew's Hospital, and the specimen (Ser. 1 ; 232) tells all the history that can, or perhaps need, be given. She had an aperture in the hard palate, and for remedy of its annoyance, used to wear a bung, or cork, in it. But the constant pressure of so rough an obturator produced absorption of the edges of the opening, making it constantly larger, and requiring that the cork should be often wound-round with tape to fit the widening gap. And thus the remedy went on increasing the disease, till, of all the palatine portions of the upper maxillary and palate bones, nothing but their margin or outer shell remains : the rest is all absorbed. The antrum is on each side obliterated by the apposition of its walls, its inner wall having probably been pushed outwards as the plug was enlarged to fit the enlarging aperture in the palate. Nearly the whole of the vomer also has been destroyed, and the superior ethmoidal cells are laid open.

Lastly, as an instance in which, in the same part, permanent pressure produced atrophy, and occasional pressure hypertrophy, I may show a Chinese woman's foot. The bandaging, and constant compression in early life, produced this diminished growth ; but afterwards, when, with all the miserable doublings-up and crowding of the toes, the foot was used in walking, the parts of pressure became the seats of corns.

We may sometimes observe the same contrast after amputations. A hole may be absorbed in an upper flap where it lies on the end of the bone, and is subject to the constant pressure of its own weight ; but, in older stumps,

the greater occasional pressure on the artificial limb leads to thickening and hardening of the parts.

These examples, then, may suffice to show, as I have said, that constant pressure on a part produces absorption ; occasional pressure (especially if combined with friction) produces thickening or hypertrophy ; and that these result whatever be the direction of the pressure. And, yet, let me add that Mr. Hunter was not far wrong,—he never was ; for nearly all pressures from without are occasional and intermittent, and nearly all pressures from within, arising, as they do, from the growth of tumours, the enlargement of abscesses, and the like, are constant.

LECTURE V.

ATROPHY : DEGENERATION.

I PROPOSE now to consider the subject of Atrophy ; the very contrary of the hypertrophy which I endeavoured to elucidate in the last two lectures.

By atrophy is commonly implied, not the cessation or total privation of the formative process in a part, but its deficiency ; and, as I limited hypertrophy to the cases in which an increased power is acquired for a part by the growth, or by the development, of healthy tissue ; so shall atrophy be here taken to mean only that process by which a part either simply wastes and is reduced in size, with little or no change of texture, or else, gradually and regularly degenerates.

By the terms of this limitation it is implied, that, as there are two modes of hypertrophy, the one with growth, the other with development ; so there are two modes of atrophy, the one with simple decrease, the other with degeneration, of tissue. In both, there is a loss of functional power in the part ; but in one, this loss is due to the deficient quantity, in the other to the deteriorated quality, of the tissue. But, as in hypertrophy the development and the growth of the affected part usually concur, so, in atrophy, a part which becomes smaller usually also degenerates, and one which degenerates usually becomes smaller. Still, one or other of these, either the decrease or the degeneration,

commonly prevails ; and we shall see reasons why the distinction is very necessary to be made.

Let me first state, and even at some length, what is to be understood by degeneration, and how its effects may be distinguished from those of disease.

I implied in a former lecture, that the maintenance of a part in its nutrition must not be understood as being the maintenance of an unchanged state : rather, each part may be said to present a series of minute progressive changes, slowly effected, and consistent with that exercise of its functions which is most appropriate to the successive periods of its existence.

Now, after a certain length of life, these changes accumulate into a very noticeable deterioration of all, or nearly all, parts of the body ; and they suffer a manifest loss of functional power. Thus changed, we say they are degenerate : these accumulated changes are the signs of decay, the infirmities of age, the senile atrophy. They are the indications of defective formative power, and often speak more plainly of old age than do the years a man may have counted ; they testify that the power which prevailed over the waste of the body in childhood and youth, and maintained the balance in vigorous manhood, has now failed : as the tide, after a flood and a period of rest, turns and ebbs down.

All the expressions usually employed about these changes imply that they are not regarded as the results of disease : nor should they be ; they are, or may be, completely normal ; and were it not that the forces which are efficient in degeneration are, probably, very different from those which actuate the formative processes, we might justly call the degeneration of advanced age another normal method of nutrition. For, to degenerate and die is as normal as to be developed and live : the expansion of growth, and the full

strength of manhood, are not more natural than the decay and feebleness of a timely old age; not more natural, because not more in accordance with constant laws, as observed in ordinary conditions. As the development of the whole being, and of every element of its tissues, is according to certain laws, so is the whole process regulated, by which all that has life will, as of its own workings, cease to live. The definition of life that Bichat gave is, in this view, as untrue as it is illogical. Life is so far from being "the sum of the functions that resist death," that it is a constant part of the history of life that its exercise leads naturally to decay, and through decay to death.

Of the manner in which this decay or degeneration of organisms ensues we know but little. Till within the last few years the subject of degenerations was scarcely pursued: and, even of late, the inquiries, which ought to range over the whole field of living nature, have been almost exclusively limited to the human body. The study of development has always had precedence in the choice of all the best workers in physiological science. They who have devoted many years of laborious thought and observation to the study of the changes by which the living being is developed from rudiment to perfection, have given fewer hours to the investigation of those by which, from that perfection, it naturally descends into decay and death. Almost the only essays at a general illustration of the subject have issued in the ridiculous notion that, as the body grows old, so it retrogrades into a lower station in the scale of animal creation. The flattened cornea is supposed to degrade the old man to the level of the fish; while the *arcus senilis*, by a fancied correspondence with an osseous sclerotic ring, maintains him in the eminence of a bird; his dry thick cuticle makes him like the pachydermata; and his shrivelled spleen approxi-

mates him to the humility of the mollusk. One can only commend such day-dreams to the modern supporters of the doctrine of transmutation of species ; and they might, indeed, form an appropriate supplement to their scheme, if they would maintain that, in these latter days, our species is destined to degenerate into lower and yet lower forms, descending through the grades by which, in by-gone times, it ascended to its climax in humanity.

We cannot but wonder at the comparative neglect with which wiser men than these philosophers have treated a study so full at once of importance and of interest as this of the natural degeneration of the body. It could not be without interest to watch the changes of the body as life naturally ebbs ; changes, by which all is undone that the formative force in development achieved ; by which all that was gathered from the inorganic world, impressed with life, and fashioned to organic form, is restored to the masses of dead matter ; to trace how life gives back to death the elements on which it had subsisted ; the progress of that decay through which, as by a common path, the brutes pass to their annihilation, and man to immortality. Without a knowledge of these things our science of life is very partial, very incomplete. And the study of them would not lack that peculiar interest which appertains to inquiries into final causes. For all the changes of natural decay or degeneration in living beings indicate this design ; that, being gradual approximations to the inorganic state of matter, they lead to conditions in which the elements of the body, instead of being on a sudden and with violence dispersed, may be collected into those lower combinations in which they may best rejoin the inorganic world ; they are such, that each creature may be said to die through that series of changes which may best fit it, after death, to discharge its share in the economy of the

world, either by supplying nutriment to other organisms, or by taking its right part in the adjustment of the balance held between the organic and the inorganic masses.

Nor would the student of the design of these degenerations do well to omit all thought of their adaptation, in our own case, to the highest purposes of our existence. When, in the progress of the "calm decay" of age, the outward senses, and all the faculties to which they minister, grow dim and faint, it may be on purpose that the Spirit may be invigorate and undisturbed in the contemplation of the brightening future; that, with daily renewed strength, it may free itself from the encumbrance of all sensuous things, or may retain only those fragments of thought or intellectual knowledge which, though gathered upon earth, yet bear the marks of truth, and being Truth, may mingle with the Truth from Heaven, and form part of those things in which Spirits of infinite purity and knowledge may be exercised.

Moreover (and this is in the closest relation to my present subject), the changes of natural degeneration in advanced life have a direct importance in all pathology; because they may guide us to the interpretation of many similar anomalies which, while they occur in earlier life, we are apt to call diseases, but which are only premature degenerations, and are to be considered, therefore, as methods of atrophy; as defects, rather than as perversions, of the nutritive process; or as diseases, only in consideration of the time of their occurrence.*

* One can here have in view only the cases in which the degeneration affects the whole, or some considerable part, of an organ; for it is very probable that some of the degenerations which we see *en masse* in the organs of the old, or in the seats of premature defect of nutrition, are the same as occur naturally in the elementary structures of parts, previous to their being absorbed and replaced, as it were by one particle at a time, in the regular process of nutrition.

The changes that mark the progress of natural decay or degeneration in old age, and that may, therefore, be regarded as the typical instances of simply defective nutrition, seem to be these:—1. Wasting or withering; the latter term may imply the usually coincident wasting and drying which constitute the emaciation of a tissue. 2. Fatty degeneration, including many of what have been called granular degenerations. 3. Earthy degeneration, or calcification. 4. Pigmental degeneration. 5. Thickening of primary membranes.

Of each of these let me cite one or two examples.

Of *withering*, or wasting and drying, which is perhaps the commonest form of atrophy, we have abundant instances in the emaciation of old age; in which, while some parts are removed by complete absorption, others are only decreased in size, and lose the succulency of earlier life.

The *fatty degeneration* in senility is best shown, as a general occurrence, in the increasing obesity which some present at the onset of old age, and in the general fact that there is more fatty matter in all the tissues, and most evidently in the bones, than there is in earlier life; while, as local senile fatty degenerations, we find the *arcus senilis*, or fatty degeneration of the cornea, and the accumulating fatty or atheromatous degenerations of arteries.

The *calcareous degeneration* is, in old age, displayed in the gradually increasing proportion of earthy matter in the bones; in the extension of ossification to cartilages, which, in all the period of vigour, had retained their embryonic state; and in the increasing tendency to earthy deposits in the arteries, and other parts.

The *pigmental degeneration* has its best instances in the gradually accumulating black pigment spotting and streaking the lungs; in the slate or ash-colour which is commonly seen in the thin mucous membranes of the stomach and in-

testines of old persons ; and in the black spotting of the arteries of some animals, in which pigment seems to hold the place of the fatty degenerations so usual in our own arteries.

Of the *thickening of primary membranes* we have indications in the usual thickening of the tubules of the testes, and, I think, of some other glands, as their function diminishes in old age ; in the opaque white thickening of the primary or inner membrane of nearly all blood-vessels ; and in the thickening of the walls of cartilage-cells in senile and some other ossifications. To this, also, we have a strong analogy in the thickening of the cell-walls of the heart-wood of plants.

These changes, singly or in various combinations, constitute the most evident degenerations of old age in man. Their combinations give rise to numerous varieties in their appearance ; such as, *e. g.*, the increase of both fatty and earthy matter in old bones ; the dry, withered, and darkly-tinted condition of the epidermis ; the coincident fatty and calcareous deposits in the arteries ; the thickened walls and fatty contents of the seminal tubes. But, at present, I need not dwell on these ; nor on the conditions which determine the occurrence of one rather than another mode of degeneration ; for these I cannot tell.

Now, if we observe the conditions in which these senile, and therefore typical, examples of degeneration are imitated in earlier life, they are such as indicate that the changes are still to be ascribed to a defect, not to a perversion, of the conditions of nutrition or of the vital forces.

Thus, these changes are all especially apt to occur in a part of which the functions are abrogated : a motionless limb wastes or becomes fatty as surely as an old one does. They are found ensuing when one or more of the conditions of nutrition are removed, not changed. For example,

a fatty degeneration of part of a heart may ensue when, through disease of a coronary artery, its supply of blood is diminished. They often occur in parts that fail to attain the development for which they seemed to be intended. Thus fatty degeneration usually ensues in the cells of unfruitful Graafian vesicles.* In short, all their history, when we can trace it, is that of atrophies.

We may therefore safely hold, that, as the changes to which the several tissues are naturally prone in old age are certainly the results of defect, not of perversion, of the nutritive process, so are the corresponding changes when they happen in earlier life; although, through their appearing prematurely, they may bear the features of disease.

The distinction between degeneration and disease is essential, though often it may be obscure. Degeneration, as to its process, is natural, though it may be premature; disease is always unnatural: the one has its origin within, the other without, the body: the one is constant, the other as various as the external conditions in which it may arise: to the one we are prone, to the other only liable.

The general diagnostic characters of degenerations are chiefly these:—

1. They are such changes as may be observed naturally occurring, in one or more parts of the body, at the approach of the natural termination of life, or, if not then beginning, yet then regularly increasing.

2. They are changes in which the new material is of lower chemical composition, *i. e.*, is less remote from inorganic matter, than that of which it takes the place. Thus fat is lower than any nitrogenous organic compound, and gelatine lower than albumen, and earthy matter lower than all these.

3. In structure, the degenerate part is less developed than

* Reinhardt, in Traube's Beiträge, B. i. p. 145.

that of which it takes the place : it is either more like inorganic matter, or less advanced beyond the form of the mere granule or the simplest cell. Thus, the approach to crystalline form in the earthy matter of bones, and the crystals in certain old vegetable cells, are characteristic of degeneration ; and so are the granules of pigment and of many granular degenerations, and the globules of oil that may replace muscular fibres or the contents of gland-cells, and the crystals of cholestearine that are often mingled with the fatty and earthy deposits.

4. In function, the part has less power in its degenerate than in its natural state.

5. In its nutrition, it is the seat of less frequent and less active change, and without capacity of growth, or of development.

Such are the characters by which in general we might separate the processes and results of degeneration from those of disease, and of natural nutrition. But we must remember always that the process of degeneration may concur with either of those from which, in its typical examples, it may be so clearly separated. It may mingle with development ; or, at least, by a process of degeneration, a part may become adapted to a more developed condition of the system to which it belongs. So it is in the process of ossification. It is usual to speak of cartilage as being *developed* into bone, and to regard bone as the more developed and more highly organised of the two tissues. But I think it is only in a very limited sense that this mode of expression is just. Professor Owen, in some admirable remarks* on the cartilaginous state of the endo-skeleton of Chondropterygian fishes, has said—" I know not why a flexible vascular animal substance should be supposed to be raised in the histological scale

* Lectures on Comparative Anatomy, vol. ii. p. 146.

because it has become impregnated, and, as it were, petrified by the abundant intussusception of earthy salts in its areolar tissue. It is perfectly intelligible that this accelerated progress to the inorganic state may be requisite for some special office of such calcified parts in the individual economy ; but not, therefore, that it is an absolute elevation of such parts in the series of animal tissues." Let me add, that all that one sees of the life of cartilage, in the narrower survey of the higher mammalia, is conformable with this view, and would lead us to speak of its change into bone as a degeneration, rather than a development. The change is effected not only in the vigour of life, but as constantly, in certain parts, in its decay ; and, whenever it is effected, the part that has become bone almost ceases to grow, except by superaddition : the interstitial changes of normal nutrition are reduced to their lowest stage. Cartilage, too, is less frequently and less perfectly repaired after injury than bone is ; and its repair is commonly effected by the production of bone ; yet it is contrary to all analogy for a lower tissue to be repaired by the formation of a higher one. It may be added that the granular, and in some instances even crystalline, form, in which the earthy matter of bone is deposited, is inconsistent with the supposition that its animal matter has acquired a higher development than it had before in the state of cartilage. So far, therefore, as its position in the series of animal tissues is concerned, bone should be placed below cartilage ; as a tissue which has degenerated into a state of less active life, and has acquired characters that approximate it to the more lowly organised and to the inorganic substances. An osseous skeleton is, indeed, proper to the most highly developed state of the individual, and in this relative view bone appears superior to cartilage : but, with as much right, in the same view, the atrophied thymus gland, and the renal capsules almost arrested in their growth, might claim to be regarded as developments from their foetal state ;

for these, also, are normal parts of the more perfect organism : they are like the degenerate members of an ennobled society, except in that, in their humiliation, they augment the common weal.

The points of contact, and even of complete fusion, are yet more numerous between development and disease. In many diseases, probably even in the whole class of inflammations, a degeneration of the affected tissue is a constituent part of the morbid process ; and in many cases we must still doubt whether the changes of texture that we observe are the results of degeneration or of disease. Among these are the instances of the simple softening of certain organs, such as the brain and spinal cord, and the liquefactions of inflammatory exudations in the suppurative process. If we limit the term degeneration to the changes that imitate the typical examples of old age, these changes cannot be included under it ; but they may be, if we consider the conditions in which they occur, and the mere decrease of power which some of them manifest. The softening of the brain and spinal cord, for example, occurs in some cases through mere defect of blood ; in some through mere abrogation of function ; it is often concurrent with distinct signs of atrophy ; and, as I shall describe in the next lecture, it is attended with changes that closely imitate those of fatty degeneration. On the whole, therefore, while admitting the difficulty that must often occur in endeavouring to separate such changes as these from the effects of disease, or of local death, yet I think we should do well to classify them under such a title as that of "liquefactive degeneration."

The sum of this discussion respecting degenerations is as follows :—We observe certain changes naturally ensuing in the tissues during advanced age, and we ascribe these to defect, not to disorder, of the formative process : we notice the same or similar changes in earlier life, and we refer

them to a similar defect, and class them as methods of atrophy: we seem justified in thus regarding them, by the general fact that they often have the same origin, and are concurrent, with the atrophy which is attended with merely defective quantity of tissue; and lastly, we regard certain changes of texture, such as some forms of softening of organs, as degenerations or atrophies, because, though they are not natural in old age, they occur in nearly the same conditions, and manifest some of the same characters, as the atrophies which imitate those of senility.

Among the degenerations that I have enumerated, only one has been very carefully studied, namely, the fatty degeneration. This deserves a full description, first, because of its own great importance in pathology, for there is scarcely a natural structure or a product of disease in which it may not occur; and secondly, for its illustration of the general doctrine of defective nutrition, and for guidance in the study of the degenerations that are at present less understood. For we may be nearly sure, that general truths, deduced from examples of fatty degeneration, will hold equally of the other forms, and especially of the calcareous and pigmental; between which and the fatty degenerations there are so many obvious features of close resemblance, that I shall content myself, having enumerated them, with merely referring to the examples of them that will be described in future lectures.*

The anatomical characters of many examples of fatty degeneration will be described in the next and in subsequent lectures. Their principal general feature is, that in the place of the proper substance of an elemental structure, *e. g.* in the place of the contents or the nucleus of a cell, or in

* The index will afford at once a sufficient guide to these examples.

the very substance of a simple membrane, a blastema, or a fibre, minute particles or granules are seen, which are recognized as consisting of oily or fatty matter, by their peculiar refraction of light, their solubility in ether, their aptness to coalesce into larger oil-drops, and, when they are very abundant, by the greasiness of the whole tissue, its burning with a bright flame, and its yielding to analysis an unusual quantity of fatty matter. In examining organs in the state of fatty degeneration, we may commonly see the progress of the change in the gradual increase of the fatty particles. Some cells, for example, may appear quite healthy; some may deviate from health only in containing two or three shining, black-bordered, oil-particles; in others, these are increased, and a large part of the cell-cavity is filled with minute oil-particles, or with one or more larger oil-drops; and in others, the contents of the cell have given place to a single cluster of oil-drops. In this last case, the degeneration is nearly complete: the transformed cell is called a "granule-cell," or, when, as it often happens, the cell-wall has wasted and disappeared, it is a "granule-mass;" and the last stage of degeneration is that such masses may break up, their constituent molecules may dispart, and the tissue which was an aggregate of nucleated cells may become little more than a mass of molecules or drops of oily matter.

It is probably due in part to such disintegration of degenerate cells, that, in most organs thus degenerate, abundant fatty matter is found free, that is, lying in drops not enclosed, among the proper constituents of the tissue. But this free fat is also derived, in part, from the degeneration of inter-cellular substance, which is usually concurrent with that ensuing in the cells; and in some cases (as Virchow has observed in the liver) it so follows the arrange-

ment of minute blood-vessels that it may be considered as the residue of a direct deposit or exudation from them.

In most instances the fatty degeneration affects, first and chiefly, as I have described it, the contents of cells or tubules, or the proper substance of membrane or other tissue. And when it thus happens, the nuclei almost always waste, and either shrivel or disappear after gradually fading in their outlines. This may be commonly seen in the fatty degeneration of the renal and hepatic cells, and of the muscular fibres; and it is a fact of some significance, when we remember the constancy and abundance of nuclei in actively growing parts. But, in certain cases, as in fatty degeneration of cartilages, the change appears to begin in the nuclei, which are gradually transformed into granule masses, while the cell-wall may remain unchanged, or may become thickly walled or laminated, or may coalesce with the surrounding tissue.

Such a transformation of a nucleus, while it retains its place and general form, might at once suggest that the fatty matter which collects in these degenerations is not introduced from without into the cells or other elements of the tissues; that it is not placed in them, as it may be in the parts around them, as a morbid deposit, or exudation from the bloodvessels; but rather is one of the products and residues of some chemical transformation which they undergo when the proper nutritive changes are suspended. We might derive the same suggestion from the similarly degenerate muscular fibres; in which we may often find the fat particles arranged in the same manner as the proper constituents of the fibrils, and looking as if there were a gradual transformation of the "sarcous elements" into the little oily particles, which, by clustering, and then by fusion, at length compose the larger oil-drops.

We gain other and better evidence of the fatty matter being derived from chemical changes in the tissue that is degenerate, from many other sources. Such changes are exemplified in the production of fatty matters during the spontaneous decompositions of nitrogenous substances. Many instances* of this are known, but none are so appropriate as the formation of adipocere in muscular tissue. Here, as Dr. Quain discovered, the places of the muscular fibres, blood-vessels, and nerves, are occupied by fatty matter, which could not have existed in them during life, which is far too abundant to have been derived from changes in the fatty matter that they naturally contain, and which, in confused crystals, retains their natural shape, size, and arrangement. And Dr. Quain has completed the evidence of the chemical nature of these degenerative changes, by an artificial imitation of them. He has shown that the textures of hearts (and the same is true of other parts), when placed in very dilute nitric acid, or in diluted spirit, pass into a condition exactly resembling that of the fatty degeneration which I have been describing.† No fact could be more apposite to prove that this form of degeneration is an atrophy; for we may be very sure that when imitable chemistry prevails in a part, the forces of life, even those of morbid life, are defective or suspended in it.

* Many are collected by Virchow, in his *Archiv*, B. i. p. 167; and others by Dr. Quain, *Med. Chir. Trans.* vol. xxxiii. p. 140, et seq. The facts concerning the formation of sugar from nitrogenous compounds in the liver are of the same kind.

† Dr. Quain has candidly referred to many previous observers by whom similar changes were recognized; but the honour of the full proof, and of the right use of it, belong to himself alone. Respecting the method of the chemical transformations by which the change is accomplished, the best essay is, I think, that of Virchow (*Archiv*, B. i. p. 152).

The whole history of fatty degenerations concurs to prove that they are the result of defect, not of disease, of the nutritive process; and that they may be therefore classed with the atrophy which we recognize in merely diminished quantity of formation. Let me point out the chief features of this history: for even some repetition of the earlier part of the lecture will be justified by the utility of assigning their right place in pathology to changes of which (as is the case with all these degenerations) we are every year gathering new and very important illustrations.

I have said that the types or standards of degenerations are the changes naturally ensuing in old age. Now, accumulations of fat, which in many parts assume the forms of the fatty degeneration of tissues, are striking characteristics of old age, and especially of the commencement of senile infirmities. The results of senile atrophy are not, indeed, the same in all persons: rather, you find among old people, and you might almost thus arrange them into two classes, the lean and the fat; and these, as you may see them in any asylum for the aged, impersonate the two kinds of atrophy I have spoken of, as the withering and the fatty degenerations.

Some people, as they grow old, seem only to wither and dry up; sharp-featured, shrivelled, spinous old folk, yet withal wiry and tough, clinging to life, and letting death have them, as it were, by small instalments slowly paid. Such are the "lean and slippered pantaloons;" and their "shrunk shanks" declare the pervading atrophy.

Others, women more often than men, as old and as ill-nourished as these, yet make a far different appearance. With these the first sign of old age is that they grow fat; and this abides with them till, it may be, in a last illness sharper than old age, they are robbed even of their fat. These, too, when old age sets in, become puffy, short-

winded, pot-bellied, pale and flabby; their skin hangs, not in wrinkles, but in rolls; and their voice, instead of rising "towards childish treble," becomes gruff and husky.*

These classes of old people, I repeat, may represent the two chief forms of atrophy; of that with decrease, and that with fatty or other degeneration, of tissues. In those of the first class you find all the tissues healthy, hardly altered from the time of vigour. I examined the muscles of such an one; a woman, 76 years old, very lean, emaciated, and shrivelled. The fibres were rather soft, yet nearly as ruddy and as strongly marked as those of a vigorous man; her skin, too, was tough and dry; her bones, slender indeed, yet hard and clean; her defect was a simple defect of quantity, and of moisture.

But in those that grow fat as they grow old, you find, in all the tissues alike, bulk with imperfect texture; there is fat laid between, and even within, the muscular fibres; fat about and in the fibres of the heart, in the kidneys, and all the vessels; their bones are so greasy that no art can clean them: and they are apt to die through fatty degeneration of some important part, such as the heart, the minute cerebral blood-vessels, or the emphysematous lungs. The defect of all these tissues is the defect of quality.

Now, I do not pretend to account for this great difference in the concomitants of the other infirmities of old age in different people. The explanation probably lies far among the mysteries of the chemical physiology of nutrition, of the

* Mr. Barlow, in some admirably written "General Observations on Fatty Degeneration," (*Medical Times and Gazette*, May 15th, 1852,) has pointed out that the climacteric disease, described by Sir H. Hallford, and the "Decline of the Vital Powers in Old Age," described by Dr. Marshall Hall, are probably, in great measure, dependent on such fatty degeneration as these persons extremely exemplify.

formation of fat, and of respiratory excretion ; and we may hope to find it when we know why, out of the same diet, and under all the same external conditions, one class of men, even in health and vigour, store up abundant fat, and another class excrete the elements of fat. In relation, however, to the present subject, the main point is, that the similarity of the conditions in which they occur implies similarity in the essential nature of the two changes, and that the defective quantity and the defective quality of the tissues are both atrophies.

The same conclusion may be drawn from the frequent coincidence of the two methods of degeneration in the same part. In the limbs, the most common form of atrophy from disease is manifested in diminution of size, together with increase in the fatty matter combined with the muscles and bones. Such is the condition usually displayed by the bones and muscles of paralysed limbs ; in the majority of atrophied stumps after amputation ; and in many other similar cases.

In like manner, the fatty degeneration of a part is commonly seen as the consequence of the very causes which, in other instances, give rise to simple wasting or emaciation of the same part. Thus, when the function of a part is abrogated, from whatever cause, the part may in one person shrink, in another degenerate into fat. The emaciation of a paralysed limb is a familiar object : but in some cases the muscles of paralysed limbs are hardly reduced in size, but are all transformed into fat. In the College-Museum there is a pancreas, with a cancerous tumour pressing on its duct, and all behind the part obliterated is degenerated into fat ; and in the Museum of St. Bartholomew's there is also a pancreas, the duct of which was obliterated ; but in this, the part behind the obstruction is simply shrivelled, dry, hard, and scarcely lobulated. So, too, among the bones

atrophied in different bed-ridden persons, some are exceedingly light, small, and dry : others are not small, but very greasy, full of fatty matter. Either of these results, also or the two mingled in various proportions, may result from defective supply of blood ; as in the cases of atrophy of parts of bones after fractures, as described by Mr. Curling to which I shall have again to refer. So that from these, and from many other cases hereafter to be mentioned, we may say generally, that nearly all the ordinary causes of atrophy may produce, in any part, in one case reduction of size, in another fatty degeneration, in another a concurrence of the two.

Much yet remains to be said of this important change : but it will be more appropriate to the next and other lectures, in which I shall describe the fatty degenerations of several parts, and of the products of inflammation and other diseases, as well as that remarkable form of the degeneration which ensues, with the rapidity of an acute disease, in the proper textures of some inflamed parts. It seems only necessary, in conclusion, to state that there appears no necessary, or even frequent, connection between the fatty degeneration of any organ in particular, and that general tendency to the formation of fat which constitutes obesity. No doubt, a person, especially an elderly one, who has a natural tendency, even when in health, to become corpulent, will, *cæteris paribus*, be more likely to have fatty degeneration, than to have a wasting atrophy, in any organ which may fall into the conditions in which these changes originate. And, as a general rule, spirit-drinking, and the excessive use of hydro-carbonous articles of food, while favouring a general formation of fat, are apt to give rise to special fatty degeneration in the liver, or some other organ. Yet, on the other hand, one commonly finds the proper elements of the tissues—the heart, the liver, and the rest—quite healthy

in men who are very corpulent. The muscular fibres of the heart, or of the voluntary muscles, may be imbedded in adipose tissue, and yet may be themselves free from the least degeneration. So, also, the hepatic cells may be nearly free from fat within, though there be much oil around them. Fat accumulated in tissue round the elements of a part is a very different, probably an essentially different, thing from fat within them ; the one is compatible with perfect strength, the other is always a sign of loss of power. In the muscles of some fish, such as the eel, it is hard to get a clear sight of the fibres, the oily matter around them is so abundant : but the fibres are peculiarly strong, and, in their own texture, make a striking contrast with the fibres of a degenerate muscle, in which the fat is, in great part, within.

The same essential distinction between general and local fat-formation, though they may often coincide, is shown in the fact that the local formation very often happens in those whose general condition is that of emaciation, as in the phthisical and chlorotic.

On the whole, therefore, we must conclude that something much more than a general tendency to form fat, or a general excess of fat in the blood, is necessary to produce a local fatty degeneration. The general conditions are favourable, but not essential, to this form of atrophy.

LECTURE VI.

ATROPHY.

THE last lecture was chiefly occupied with a general account of those changes of texture which are to be regarded as atrophies ; and now, having pointed out what affections may be classed under this term, the whole subject may be more largely illustrated by particular examples.

First, as to the conditions in which atrophy, whether with decrease or with degeneration, may ensue. Many of them may be most easily explained as the very contraries of the conditions in which hypertrophy originates. Thus, as we have seen that when a part is, within certain limits, over-exercised, it is over-nourished ; so, if a part be used less than is proper, it suffers atrophy. For instance, in the Museum of St. Bartholomew's (Ser. 12 ; 57), is the heart of a man fifty years old, who died with cancer of the stomach in extreme emaciation. It is extremely small, and weighed only five ounces four drachms ; whereas, according to the estimates of Dr. Clendinning, in a healthy man of the same age the heart weighs upwards of nine ounces. But, small as it is, this heart was adapted to the work it had to do ; and in this adaptation we have the purpose of its atrophy. For, because of his cancer, the man had less blood, and needed less force of the heart to propel it : so that, in direct opposition to what I described as the course

of events in hypertrophy, here, as the quantity of blood diminished, and the waste of the heart by exercise in propelling it diminished, so the repair of the waste diminished somewhat more than the waste itself did; and the heart, though less wasted, became smaller, till it was only large enough for the propulsion of the scanty supply of blood.

The same may be said of a heart of which there is a drawing in the same Museum. It was taken from a woman twenty-two years old, who died with diabetes. It weighed only five ounces; yet, doubtless, it was enough for her impoverished supply of blood.

It would be superfluous to describe many instances of atrophy through defective exercise, or abrogated function of parts. The wasted and degenerate limbs of the bed-ridden, the shrunken brains of the aged and the imbecile, the withered ovaries and uteri of many barren women, are good examples of defective nutrition adapted to defective exercise of function: and so are the atrophied distal parts of nerves whose trunks have been divided, and the atrophied columns of the spinal cord that correspond with inactive portions of the brain. The rapid degeneration and removal of the tissue of the uterus after parturition, and the rapid disappearances of temporary organs of various kinds, are as striking examples of atrophy following the abrogation or completion of office. To some of these examples I shall again refer.

It is in similar contrast with the history of increased growths, that, as an excess of the constituents of which a tissue may form itself produces hypertrophy of that tissue, so may defect of those constituents produce atrophy. Thus, the quantity of adipose tissue diminishes even below what is natural to the several parts, as often as the fat-making constituents are deficient in the food, and therefore in the blood. So, the formation of bones is defective during deficiency of

the supply of bone-earths; the mammary glands waste when the materials for the formation of milk are imperfectly supplied; and the whole body wastes in general defect or poverty of blood.

Again, as I showed instances in which the increased flow of healthy blood through a part produced hypertrophy, so are there more numerous examples of merely defective nutrition in consequence of a diminished supply of blood. Some of the most striking of these were first described by Mr. Curling,* in cases of fractured femora and other bones, showing atrophy of that portion which, by the fracture, was cut-off from the supply of blood through the great nutritive or medullary artery. The consequence of the withdrawal of so much of the blood from the upper or lower fragment, according to the position of the fracture, is not death; for the anastomosis between the vessels of the wall and those of the medullary tissue of the bone is enough to support life, though not enough to support vigorous nutrition; but the frequent consequence of the fracture is an atrophy of the part thus deprived of a portion of its ready supply of blood.

Similar instances are seen in the decrease or degeneration of portions of hearts when single branches of a coronary artery are obstructed; † in the wasting of a portion of kidney when a branch of a renal artery is closed; ‡ and in local softening of the brain, with obliteration of single cerebral arteries. §

In all these instances we see that conditions contrary to those giving rise to hypertrophy produce atrophy. But

* *Medico-Chirurg. Trans.* vol. xx.

† Quain, *Medico-Chir. Trans.* xxxiii. p. 148; Virchow, *Archiv*, iv. p. 387.

‡ Simon, *Lectures on Pathology*, p. 94.

§ Kirkes, *Med.-Chir. Trans.* vol. xxxv.

there are many other conditions from which atrophy in a part may ensue; defects in quantity, or in the constitution, of the blood; defective or disturbed nervous influence, as through excessive mental exertion; the disturbances of disease or injury, as in inflammations, specific morbid infiltrations, &c. In short, whatever interferes with or interrupts any of those conditions which I enumerated as essential to healthy nutrition, may give rise to atrophy, either general or local. The clinical history of the fatty degeneration of the heart, so largely illustrated by Dr. Ormerod* and Dr. Quain,† may best prove how multifiform are the events from which the atrophy of a single organ may arise.

But besides all the instances in which atrophy of a part may arise as a secondary process, there are others in which we are so unable to trace its precedents, that we are tempted to speak of it as primary, or spontaneous, in the same sense as we might so call the natural wasting of the Wolffian bodies, the thymus, and other temporary organs. It is as if an atrophy of old age, instead of affecting all parts simultaneously, took place prematurely in one.

Whatever the true explanation may be, most of the parts of the body appear to be subject to this seemingly spontaneous atrophy; and it generally manifests itself in some form of degeneration. Its most frequent seats are the heart and arteries, the bones, muscles, liver, and kidneys; but it occurs also in the pancreas and the salivary glands, and in the testicle. It is yet more frequent in morbid products, as in the fibrinous deposits on the interior of arteries, the exudations of inflammation, and tumours of every kind.

The contrast between hypertrophy and atrophy is, thus,

* Medical Gazette, 1849.

† Medico-Chirurgical Trans., vol. xxxiii. 1850.

nearly as great in the number, as in the kind, of the conditions in which they may severally arise. And, once more, we may contrast them in regard to the mode in which the vessels and nerves adapt themselves. As a part becomes atrophied, its blood-vessels and its nerves are consequently and proportionally changed. In atrophy of the eye, the optic nerve and artery diminish; and, in a case of fatty degeneration of the adductor muscles of the thigh, in consequence of disease of the hip-joint, I found corresponding atrophy of their nerves. The atrophy of the nerves must have been, in this case, secondary: the course of events being, inaction of the muscles in consequence of the disease of the joint; then, atrophy of them in consequence of their inaction; and, finally, atrophy of the nerves following that of the muscles.

From these general considerations I proceed to speak particularly of Atrophy, as it manifests itself in some of the principal organs and tissues of the body;—and first of the Atrophy of Muscles.

The affection has been well studied in all the three forms of muscular tissue; namely, in the voluntary muscles, in the heart, and in the organic or smooth-fibred muscles; and I will describe it in each of these in order.

The voluntary muscles exhibit, in different conditions, both the chief forms of atrophy; that, namely, with decrease or wasting, and that with fatty degeneration.

In a wasted muscle, such as one sees, for example, in the limbs of those who are only emaciated, the fibres may appear almost perfectly healthy: they are rather paler, indeed, and softer, and more disposed to be tortuous, than in the natural state; for muscles are commonly withered when they are thus reduced in size; yet their transverse striæ, and all other their characteristic features, are well marked.

In the state of fatty degeneration, the whole of a voluntary muscle may appear pale, bleached, or of some yellowish or tawny hue, soft and easily torn. But a more frequent appearance is that in which fasciculi in the healthy state, and others in various degrees of degeneration, lie in parallel bands, and give the whole muscle a streaky appearance, with various hues intermediate between the ruddiness of healthy flesh, and the dull, pale, tawny-yellow, or yellowish-white, of the complete degeneration. In such a case (and this may appear remarkable) healthy primitive fibres may lie among those that are degenerated. Of the latter, some, in place of the transverse striæ, present dark very minute dots arranged in transverse lines; in others, the whole fibre has a dim, pale, granular aspect, with no definite arrangement of the granules; in others, little oil-globules adhere to the interior of the sarcolemma; and in others, such globules are collected more abundantly, and to the proportionally greater exclusion of the proper constituents of the fibres: but the characters of fatty degeneration are rarely, if ever, so well marked in the fibres of voluntary muscles as in those of the heart.

In the examination of different examples of fatty degeneration of the voluntary muscles, you may find much diversity in the tissue between the fibres and fasciculi. In some instances, the interspaces between the fasciculi are filled with cellular tissue, both more abundant and tougher than that in healthy muscle; so that it may be hard to dissect the fibres for the microscope. With this there may be no unusual quantity of fat; but, in other cases, the quantity of fat between the fibres is very great, and the fibres themselves may seem empty, or wasted, as if overwhelmed by the fat accumulating around them. In such a case, when the accumulating fat has coalesced with that which before surrounded the whole muscle, it may be difficult to find

where the muscle was ; for the whole of what belonged to it, after its degeneration, may be gone, and in its place there may remain only an obscure trace, if any, of fibrous arrangement, dependent on the position of the principal partitions of the new fatty tissue.

I cannot yet speak positively in explanation of this diversity in the state of parts between the fibres. But, I think, the increase and toughness of the cellular tissue (when it is not the product of organized inflammatory deposit) exist only in atrophied muscles which have had to resist stretching, after the manner of ligaments ; as, for example, when their antagonists are not as powerless as themselves. And the increase of fat seems to be found only when a muscle has been very long atrophied, and has remained completely at rest ; then, the fibres themselves, after degenerating, may be removed, and give place to a formation of common adipose tissue, which collects in every part that they are leaving, just as it does about shrinking kidneys, some cancers of the breast, old diseased joints, and other parts similarly circumstanced.

In either case, we must distinguish between these formations of fat outside, and those within, the fibres ; the former are in no necessary connection with the proper atrophy of the fibres, but generally appear subsequent to it ; and when they attain their highest degree, they are not to be regarded as degenerations of the muscular tissue ; for they are not, in any sense, formed out of it, though they occupy the place from which it was removed.

The condition in which atrophy of the voluntary muscles most commonly ensues is inaction. Whenever muscles lie long inactive, they either waste or degenerate ; and this whether the inactivity depend on paralysis through affection of the nervous centres or fibres, or fixity of the parts they should move, or on any other cause. The degenera-

tive process may be so rapid that, in a fortnight, muscles paralysed in hemiplegia may present a manifest change of colour : but it is commonly a much slower process.

The course of events in these cases appears to be, that the want of exercise of a muscle, whether paralysed or fixed at its ends, makes its due nutrition impossible ; and the atrophy thus brought about is the cause of loss of irritability of the muscle, *i. e.* of loss of its capacity for contracting. For the experiments of Dr. John Reid* show that loss of contractile power in a paralysed muscle is due, directly, to its imperfect nutrition, and only indirectly to the loss of connection with the nervous centres. When he divided the nerves of a frog's hind legs, and left one limb inactive, but gave the muscles of the other frequent exercise, by galvanizing the lower end of its divided nerve, he found (to state the case very briefly) that at the end of two months the exercised muscles retained their weight and texture, and their capacity of contraction ; while the inactive ones (though their irritability, it might be said, had not been exhausted by exercise), had lost half their bulk, were degenerate in texture, and had also lost some of their power of contracting. In other cases, too, he found the loss of proper texture always ensuing in the inactive state, before the power of contraction was lost.

It is doubtless the same in man. A muscle which, by no fault of its own, but through circumstances external to itself, has been prevented from acting, soon becomes incapable of acting even when the external obstacles to action are removed. Hence we may deduce a rule which ought to be acted on in practice. When a person has had hemiplegia, one commonly sees that long after the brain has, to all

* Edin. Monthly Journ. of Med. Science, May 1841. See, also, M. Brown-Sequard, in the Gaz. Médicale, No. 9, 1850.

appearance, recovered its power, or even through all the rest of life, the paralysed limbs remain incapable of action, and as motionless as at the first attack. Now, it is not likely that this abiding paralysis is the consequence of any continuing disease of the brain: rather, we must ascribe it to the imperfect condition into which the muscles and nerve-fibres have fallen during their inaction. So long as the state of the brain makes voluntary action impossible, the cord, nerves, and muscles, are suffering atrophy; then, when the brain recovers, they are not in a state to obey its impulses, because they are degenerate; and thus, their inaction continuing, they degenerate more and more, and all remedy becomes impossible. If this be true, Dr. Reid's experiments suggest the remedy. When muscles are paralysed through affection of the nervous system, we ought to give them artificial exercise: they should be often put in action by electricity or otherwise; their action, though thus artificial, will ensure their nutrition; and then, when the nervous system recovers, they may be in a condition ready to act with it.

You will find this suggestion ingeniously supported by my friend Mr. W. F. Barlow, in a paper published by him in the *Lancet*. In one case, in which I could act upon it, the result was encouraging. A little girl, about eight years old, had angular curvature and complete loss of voluntary movement in the lower extremities. This had existed some weeks, but as I found she had reflex movements, the legs twitching in a very disorderly way as often as the soles were touched, I advised that the limbs should be put in active exercise, for about an hour two or three times a day, by tickling the feet, or in some similar way. The result was, that when, several weeks afterwards, the spinal cord recovered, and she could again direct the effort of the will to the lower limbs, the recovery of strength was speedy and complete; more so, I think, than if, in the paralysed con-

dition, the muscles and nerves had been left to the progress of the atrophy. A similar paralysis, about two years later, occurred again, and was similarly recovered from.

The hindered action of muscles, though the most frequent, is not the only condition from which their atrophy may ensue. They waste, together with all the rest of the body, in most emaciating diseases; as, for example, in phthisis: and they may degenerate into fat, in concert with other tissues, in a generally defective nutrition.

But, besides the general atrophies of muscles, a similar affection occurs sometimes as a primary or spontaneous affection of one or more muscles. We find sometimes one of the muscles of an extremity, or of the back, thoroughly atrophied, while the others are healthy; and no account can be given of its failure.

It is not very unfrequent to find a portion of the lower and posterior part of the recti abdominis muscles in a state of fatty degeneration.

Rokitansky* briefly refers to a spontaneous fatty degeneration of the muscles of the calf attended with extreme pain: and Mr. Mayo† has recorded two cases of apparently spontaneous atrophy of the muscles of the shoulder, in which, in a few weeks after severe pain, but no other sign of acute inflammation, all the muscles about the shoulder became simply, but exceedingly, atrophied.

We name these spontaneous atrophies, and it may be that the defective nutrition is the first event in the abnormal chain; but, I think, we shall hereafter find that, in most of them, the degeneration is a part of some inflammatory process; for, as I shall have to describe in future lectures, there is no tissue in which it is more evident than in the muscles,

* Pathol. Anat. B. 2, S. 348.

† Outlines of Human Pathology, 1836, p. 117.

that a degeneration of the proper elements of an inflamed part is associated with the more obvious effects of inflammation.

Atrophy of the muscular substance of the heart, may, like that of which I have just been speaking, appear in either wasting or degeneration, or in a combination of the two. Of the former I mentioned examples in the beginning of the lecture, in the heart of a cancerous man, 50 years old, which weighed only five ounces four drachms; and that of a diabetic woman, 25 years old, which weighed only five ounces one drachm. Both these had deviated from the general rule of enlargement of the heart with advancing years, in adaptation to the diminished quantity of blood, and the general diminution of the body.

In these cases there is a uniform decrease of the heart: its cavities become small, and its walls proportionally thin; and the fat on its exterior diminishes, or is changed into a succulent, cedematous tissue. In other instances the cavities are dilated, without proportionate thickening, or, it may be, even with thinning of their walls. This, probably, occurs chiefly in cases of such increased obstacle to the circulation as might, in other persons, or in other conditions, engender hypertrophy of the heart. Or, the dilatation may be the consequence of wasting in a heart that was once large and strong.

But, an atrophy of the heart much more important than any of these, is that which consists in fatty degeneration.

Extreme instances of fatty degeneration of the heart have been long known. The whole, or the greater part of the heart, in such cases, may seem reduced to fat; the degenerate tissue having coalesced with that which lies on its surface, and the degeneration being accompanied by thinning and softening of the walls.

In like manner, the cases have been well known and described for which Dr. Quain proposes the name of "fatty growth," to distinguish them from the "fatty degenerations" of the heart. In these, the adipose tissue accumulates in unusual quantity on those parts of the exterior of the heart in which it naturally exists, and is found, though often emaciated and very soft, even in the thinnest people; viz. along its transverse furrow, the furrows in which the coronary vessels run, and others. From these positions, the fat dipping more and more deeply may nearly displace the fibres, and may lead to a secondary degeneration of them: but, commonly, the heart's fibres are themselves healthy, even when they lie completely imbedded in the overgrown fat.

But these conditions, and their combinations, are too well known to need that I should describe them, or refer particularly to any specimens of them, except to a sheep's heart, which is in the College Museum (No. 1529), and which shows, in an extreme degree, a method of the growth of fat which is rarely imitated, in even a trivial measure, in the human subject. It exhibits a great accumulation of fat on its surface, and its walls are thin; but the greater parts of the cavities of the ventricles and of the left auricle are occupied by large lobulated growths of suet-like fat. The weight of the fat here added to the heart is 25 ounces, and it is said that there was also a large accumulation of fat about the kidneys. But no other history of the case is extant than that the sheep was inactive, and had dyspnoea on exertion.

These cases of extreme fatty growth, or of extreme degeneration, of the heart are much rarer than those of which I have now to speak.

The most common form of fatty degeneration is that in which you find, on opening the heart, that its tissue is in

some degree paler and softer than in the natural state, and lacks that robust firmness which belongs to the vigorous heart. But what is most characteristic is, that you may see, especially just under the endocardium, spots, small blotches, or lines, like undulating or zigzag transverse bands, of pale, tawny, buff, or ochre-yellow hue, thick-set, so as to give, at a distant view, a mottled appearance. These manifestly depend not on any deposit among the fasciculi, but on some change of their tissue. For, at their borders, you find these spots gradually shaded-off, and merging into the healthy colour of the heart; and when you examine portions of such spots with the microscope, you never fail to find the fatty degeneration of the fibre.

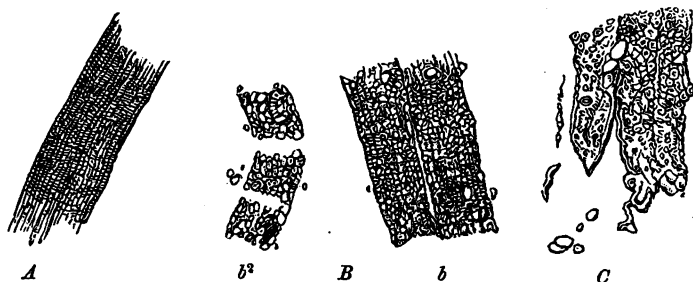
The yellow spotting, or transverse marking of the heart, may exist in the walls of all its cavities at once, or may be found in a much greater degree in one than in the others. It may exist in all parts of the thickness of the walls, or may be chiefly evident beneath the endocardium and pericardium. It is far less common in the auricles than in the ventricles; and when it exists simultaneously in all parts it is less advanced in the auricles. It is more common in the left ventricle than in the right; and in the left ventricle it is commonly most advanced on the smooth upper part of the septum, and in the two large prominent fleshy columns. Indeed, it may exist in these columns alone; and when, in such a case, the rest of the heart remains strong, may account for the occasional occurrence of rupture of the columns.

These yellow spottings of the heart, produced by degeneration of scattered portions of its fibres, are, as I have said, the most evident, as well as the most frequent, indications of its degenerative atrophy. But a similar affection may exist in a worse form, though it be less manifest:

worse, because the degeneration is more extensive and more uniform ; and less manifest, because it is less distinctly visible to the naked eye, and must be recognized by the touch rather than by the unaided sight. The whole heart feels soft, doughy, inelastic, unresisting ; it may be moulded and doubled-up like a heart beginning to decompose long after death : it seems never to have been in the state of *rigor mortis*. These conditions are more manifest when a section is made through the wall of the left ventricle. Then, if the wall be only partly cut through, the rest of it may be very easily torn, as if with separation of fibres that only stick together ; and the cut surface of the wall looks, as it were, lobulated and granular, almost like a piece of soft conglomerate gland, an appearance which is yet more striking when observed with a simple lens of about half an inch focus. In colour, the heart has not on its surface, much less on its section, the full ruddy brown of healthy heart, a colour approaching that of the strong voluntary muscle ; but is, for the most part, of a duller, dirtier, lighter brown, in some parts gradually blending with irregular marks or blotches of a paler fawn, or dead-leaf-colour.

These appearances of the degenerate heart may be variously mingled ; and they may be variously associated with overgrowths of the external fat, or with previous hypertrophy or other changes of structure in the heart. But, however much the appearances of the affection may be obscured, the general characters of softness, paleness, mottled colour, and friability, will be sufficient, if not always to prove, yet always to excite suspicion, that the fatty degeneration of the heart exists : and, if only suspicion is excited, the microscopic examination may be always decisive. The chief microscopic appearances are delineated in the adjoining sketch.

FIG. 6.*



When a portion of the heart's walls, especially if they are very soft, is dissected in the ordinary way, with needles, for the microscope, the fibres are broken into short pieces, some twice, some five or six times, as long as they are broad. The broken ends of these short pieces are usually squared; but some are round, or irregular, or cloven, and broken-off lower down. The pieces are almost always completely separated, having no appearance of even cohering at their sides, and they lie scattered disorderly.

In whichever form the degeneration is examined, you may find that, in some pieces, the transverse striæ are still well seen and undisturbed, appearing quite as in health. In more, they are interrupted or obscured by dark dots, or by glistening particles with shady black margins, like minute oil-particles scattered without order in the fibres. Where such particles are few, they appear to lie especially, or only, in contact with the interior of the sarcolemma; but, where more numerous, they appear to occupy every part of the

* *A.* Muscular fibres of the healthy human heart.

B. Fatty degeneration of the fibres of the human heart; δ , early stage; δ^2 , more advanced.

C. The same, yet more advanced, all magnified 400 times. From Dr. Quain's plates; *Med. Chir. Trans.* vol. xxxiii. pl. 3.

fibre, leaving the transverse striæ discernible only at its margins, or even completely obscuring or replacing them, and making the fibre look like a gland-tube filled with dark granules and larger glistening dark-edged fat-particles. Where these particles are very numerous in a fibre, they appear also generally larger, and more generally glistening and black-edged, like larger oil-particles.

There may be no oil-drops floating about; no fat-cells; scarcely even any of the minute particles, which are seen in the fibres, may appear out of them; the field of the microscope may be perfectly clean. In these minor respects, however, many differences exist; though I think it may be stated that the degeneration is very rarely, if ever, accompanied by any morbid product deposited between the fibres; whatever fatty matter may appear between them, is only such as has escaped from them.

As a general rule, the palest parts of the heart are most advanced in the disease; but even in microscopic portions some pieces of fibres appear hardly changed, while those all round them are completely granular.

I alluded, in the last lecture, to the defective condition of the nuclei of degenerate elemental structures. This is peculiarly well shown in the degenerate fibres of the heart. When those of a healthy heart are placed in diluted acetic acid, they display a longitudinal series of nuclei, at nearly equal distances apart, and usually lying in the middle of the presenting surface of the fibre. Such nuclei are, so far as I know, peculiar to the heart-fibres. They are large, reddish-yellow, like blood-globules, especially when the heart is very robust: they are elongated, oval, or nearly quadrilateral; and at each of their ends one almost always sees tapering groups of small, isolated, yellowish granules, like particles separated from them, and gradually withering.

But in the degenerate fibre, when the change is least advanced, the outlines of the nucleus look dim, and it loses its colour : when the change has made further progress, the nucleus cannot be seen at all, though its former place may be indicated by some of the narrow group of granules ; and in a yet later stage, when the sarcolemma appears nearly full of fatty particles, all trace is lost alike of the nucleus and of the granules.

I have spoken of fatty degeneration of the heart at this great length, both because there is no better example for illustration of the general pathology of such affections, and because it is extremely important that this condition of the heart should be recognised after death, even when no suspicion could be entertained of it during life. For it often introduces unexpected dangers into the ordinary practice of surgery : it is, I believe, not rarely the cause of sudden death after operations ; it is one of the conditions in which chloroform should be administered with more than ordinary caution. They who labour under it may be fit for all the ordinary events of calm and quiet life, but they are unable to resist the storm of a sickness, an accident, or an operation. And let it not be said that one learns little in learning too late the existence of an incurable disease ; for very often the death that has come from such a disease has been ascribed to a wrong cause, and has spoiled confidence in good men and their good measures. Nor does the caution seem unnecessary that, serious as the effects of the disease are, the change of structure may escape any but a very careful and practised examiner. For, often, the change is hardly manifest to the eye, though, while it affects the whole heart, it may have destroyed life.*

* When the lecture was delivered, in 1847, I related some cases of sudden death from this affection ; and expressed the hope that

Atrophy of the organic or smooth-fibred muscles doubtless occurs as a simple decrease of them in the thinning of the coats of the intestines, stomach, and other hollow organs, which is sometimes associated with general emaciation, or with diminished function : but the change has not been carefully studied. Of the fatty degeneration of this muscular tissue, examples are described in the muscular coats of the arteries,* which partake in the corresponding change, or atheromatous affection, of their thickened internal coats ; in the coats of the urinary bladder ; † and in the uterus. ‡ In the latter organ the change has peculiar interest ; taking place, as it does, quickly after the fulfilment of office in parturition ; affecting all the muscular fibro-cells which, during gestation, had been developed to their perfection ; and preceding their absorption and replacement by new-formed fibro-cells, like those which existed in the young and unimpregnated uterus. The series of changes thus traced

its whole clinical history would be traced by Dr. Ormerod, who helped me very much in investigating its morbid anatomy. The hope has been fulfilled far beyond my expectation by both him and Dr. R. Quain, who was, at the same time, actively occupied with a similar course of inquiry. I may therefore refer the reader to their essays, in the *Medical Gazette* for 1849, vol. ii. ; and in the *Medico-Chirurgical Transactions*, vol. xxxiii. : essays, valuable alike for the importance of their facts, and for the thoroughly scientific spirit in which they are conceived.

* Rokitansky, *Pathol. Anat.*, ii. p. 543 ; Kölliker, *Zeitschr. für wissensch. Zoologie*, i. p. 81.

† Mr. Hancock, as quoted by Mr. Barlow, *Med. Times and Gazette*, May 15, 1852.—The change of which I spoke, in this lecture, as a kind of fatty degeneration of the bladder in old people, was not proved to be degeneration of the muscular fibres : neither, I think, has this been yet proved, though it is highly probable, in the muscular coat of the gall-bladder.

‡ Kölliker, l. c. p. 73. Kilian, in Henle und Pfeufer's *Zeitschr. für rat. Medicin*, vols. viii. and ix.

by Kilian tell a complete history of nutrition, in the succession of development and growth to perfection, of discharge of function, consequent degeneration, absorption, and replacement by new structures that, in their progress, pass through the same phases as their predecessors. The production of fat in the uterine tissue confirms also the probability which I have already mentioned (p. 56), that fat is one of the usual results of the chemical change which takes place in muscular action, and is, in this relation, a substance, like the kreatine, which is also found in the uterine tissue after birth,* intermediate and transitional between the proper constituents of the tissues and the oxidised materials of excretions. It may be added, that the whole substance of the uterus and its membranes partakes of the degenerative change, and that the removal of the old tissues and the formation of new ones is so total, that, as it has been justly said, a person has a new uterus after each delivery. But the peculiarity of the case is only in that the change is accomplished quickly, manifestly, and simultaneously in a large mass of tissue: in the same sense, though at unknown times, men have often new hearts, new glands, and new brains.

In the bones we may probably consider that a calcareous degeneration occurs as a method of atrophy, in addition to those just described in the muscles: for to such a degeneration we may ascribe the increased proportion of bone-earths in the skeletons of aged persons. The augmentation of earthy constituents is not attended with increased strength of the bones: rather, they become, in old persons, thin-walled, and more easily broken; the change being

* Siegmund, in the Würzburg Verhandlungen, B. iii. H. 1.

commonly associated with both wasting and fatty degeneration, and the whole tissue being rarified. It is through this general want of compactness in their construction that old bones are weak: for, as Dr. Stark's analyses show very well, the strength of bones depends more on their compactness than on the proportion of their constituents.

I am not aware that any analyses of diseased or other bones have shown a calcareous degeneration of them, except in old age: but its frequent occurrence is highly probable. The other modes of atrophy may be more fully illustrated in the two forms already often referred to. The simple wasting of a bone is a common change. Examples have been already adduced in connection with the subject of unequal length of the limbs (p. 88), and with that of the effects of pressure (p. 91), as well as in relation to the general history of atrophies. Among many specimens in the College-Museum, the most striking is the skeleton of an hydrocephalic patient from the collection of Mr. Liston (No. 3489). It is the more remarkable, because while all the bones of the trunk and limbs are reduced, by atrophy, to exceeding thinness and lightness, the bones of the cranium are as exceedingly enlarged in adaptation to the enormous volume of their contents.

Another interesting specimen is a skull (No. 8) fitted-up by Hunter to show the movements of the edentulous lower jaw, as he has described them in his "Natural History of the Teeth." It shows the atrophy not only of the alveolar margins, but of every part of the jaws, and even of their palatine parts, and those of the palate bones, which are quite thin and transparent.

A rare specimen of atrophy of the lower jaw is shown in a case of complete osseous ankylosis of both temporo-maxillary articulations, from Mr. Howship's Museum (No. 966).

Similar atrophy of bone in its extreme state is illustrated by an example of ankylosis of the knee (No. 384), from the case described by Mr. Thurnam.* Considerable apertures are formed in the wasted walls of the femur and tibia, and they were covered-in by the periosteum alone: the whole thickness of these portions of the walls having been removed in the progress of the atrophy.

In the Museum of St. Bartholomew's is a specimen in which simple atrophy of the femora led to such fracture as, being effected by a slight force, is called spontaneous. The atrophy of these bones occurred coincidentally with extreme emaciation of all the other parts, as well as of the skeleton; an emaciation which was to be ascribed, I believe, more to starvation than to anything else. The shafts of the femora are exceedingly small, and their walls are so thin that, although their texture appears healthy, they could not resist the force of the muscles acting on the articular ends. They broke: and the result shows a remarkable example of the capacity for repair of injuries even while the process of ordinary nutrition seems almost suspended: for the fractures were firmly re-united.

I might greatly multiply examples of such simple wasting atrophy of bones; but let these suffice, that I may speak now of fatty degeneration of the bones.

I have already said that it is common, in many atrophied bones, to find an excess of fatty matter; I referred to old bones laden with fat as examples of a form of senile atrophy; and sometimes, in cases of diseased joints, the form of atrophy assumed by the disused bones is that not merely of exceeding thinness of the walls and wasting of the cancelli, but of an accumulation of soft fat filling every interstice and maintaining the size of the bone. But it is now

* Medical Gazette, vol. xxiii. p. 119.

to be added, that the bones, like other organs, are liable to a fatty degeneration, which, because of the obscurity of its origin, we must be content to call spontaneous; and this fatty degeneration of the bones is the disease which most English writers have described as *Mollities Ossium*.

The Museum of the College has a remarkably rich collection of specimens of this disease: a collection embracing specimens from nearly all the cases with whose histories we are most familiar.

Well-marked examples of the fatty degeneration are shown in No. 400. These are two femora fractured by a slight force, and, in their dried state, light, very greasy, mahogany-brown, and so soft that you may crush many parts of them with the fingers. Their excess of fat is evident; but no more of their history is known than that they came from an elderly, if not an old, man,—an Archbishop of Canterbury.

In No. 398 is a section of an humerus, affected, as many other bones of the same person were, with extreme fatty degeneration; and the Catalogue contains, with its description, a reprint of an essay, by Mr. Hunter, which escaped even the careful research of the editor of his works, Mr. Palmer. His essay is entitled, "Observations on the Case of *Mollities Ossium* described," &c., by Mr. Goodwin, in the *London Medical Journal*.* It was communicated in a letter to Dr. Simmons, the editor of that journal, and I will quote one passage, to show both what was the original appearance of the bones, and how completely Mr. Hunter's description confirms the opinion that this *mollities ossium* was really a fatty degeneration of the bones. He says, speaking of this humerus, "The component parts of the bone were totally altered, the structure being very different

* Vol. vi. 1785.

from other bones, and wholly composed of a new substance, resembling a species of fatty tumour, and giving the appearance of a spongy bone, deprived of its earth, and soaked in soft fat."

Nothing can better express the character of the change, or its similarity to the fatty degenerations of other organs, in which we find the proper substance of the part gradually changed for fat, and the whole tissue spoiled, while the size and outer form of the part remain unaltered.

The same characters are shown in the often-quoted case by Mr. Howship, of which specimens are preserved in Nos. 401-2-3. The last of these specimens shows what remained of the upper part of a femur after boiling; scarce anything besides a great quantity of white crystalline fatty matter.

It is the same with a femur (No. 403 B.) presented to the Museum by Mr. Tamplin, in the examination of which I first obtained, with the microscope, the conviction of the nature of the change which constitutes what we call molities ossium. This has the same characters as the specimens already shown, and the medulla of the bone had the bright yellow, pink, and deep crimson hues, which are so striking in many instances of the disease. But the constituents of this apparently peculiar material were, free oil in great quantity; crystals of margarine, free, or enclosed in fat-cells; a few fat-cells full of oil as in health, but many more, empty, collapsed, and rolled-up in strange and deceptive forms. The pink and crimson colours were owing to the bright tints of a part of the oil-globules, and of the nuclei and granules in the collapsed fat-cells; and there was no appearance whatever of an excess of blood in the bone, or any of its contents.

From this examination, therefore, as well as from all the other facts, I concur entirely in Mr. Curling's opinion

respecting this disease.* A specimen (No. 403 A) from the case on which he chiefly founded his opinion, and which he has very accurately described, closely resembles those I have referred to. He proposes the name "Eccentric Atrophy of Bone" to express one of the principal characters of the disease; and I would have adopted it, as preferable to "Osteoporosis," under which I think Rokitansky would include these cases, but that it seems desirable to class this affection with others to which it bears the closest analogy, by giving it the same generic name in the designation, fatty degeneration of bones.

The cases to which I have now referred include the principal examples of the disease observed and recorded in England under the name of mollities ossium; and to these, I think, may be added the case described by Mr. Solly,† for the appearances presented by the femur (No. 403 C) are strikingly similar to those in the specimens already referred to, and the material filling its medullary cavity contained abundant fatty matter.

You might ask, then, what is the real mollities ossium? or is there such a disease different from what these specimens show? I could not from my own observations answer such a question; for I have never seen a specimen which appeared to fulfil in any degree the general notion of mollities ossium, as a disease consisting in the removal of the earthy matter of bone, and the reduction of any part of the skeleton to its cartilaginous base. I do not doubt the accuracy of what others have written of such an affection: but I am sure, that the cases I have cited are not simple softenings of bone, but fatty degenerations; and that those cases must be very different to which Rokitansky refers

* Medico-Chirurgical Transactions, vol. xx.

† Ibid. vol. xxvii.

under the names of, Osteomalacia, Malakosteon, Knochenerweichung, and Rachitismus adutorum. He gives, as a characteristic of the disease, that it affects the bones of the trunk, or a part of them, much more often, and more severely, than the bones of the extremities, and occurs especially after child-bed. Now, in the cases which I have endeavoured to illustrate, the extremities, not the trunk, are the chief seats of the disease; and there is no evidence of the fatty degeneration occurring more often after delivery than in any other period or condition of life. So that, on the whole, I think we may consider there are two diseases included under the name of mollities ossium; namely, the fatty degeneration which these specimens show, and which seems to be the more frequent in England; and the simpler softening of bone, or rickets of the adult, to which Rokitansky's description alludes, and in which the bones are flexible rather than brittle, and appear reduced to their cartilaginous state. This affection seems to be more frequent than the fatty degeneration in Germany and France: and I think the only probable, well-recorded instance of its occurrence in England, is that related by Mr. Dalrymple,* Dr. Bence Jones,† and Dr. Macintyre.‡

I feel, however, that there is still much doubt respecting the relations of these affections; they are, perhaps, more nearly allied than, at first sight, they may seem; and I think some clue to their alliance may be obtained from the relation which they both have to the rickets of the young subject. The relation is best shown in the bones of the skull, and is illustrated by specimens in the College-Museum (Nos. 392 to 396, and 2857 to 2860); but I need not

* Dublin Journal of Med. Science, vol. ii. 1846.

† Philos. Trans., 1848.

‡ Medico-Chir. Trans., vol. xxxiii.

now dwell on it while wishing to give only a general account of the atrophies of bone.*

I can scarcely doubt that future inquiries will ascertain that, in every tissue, changes such as these which I have described in muscle and in bone are the results of simply defective nutrition. But I have neither knowledge nor space for more than a few additional instances. Among these, the degenerations of blood-vessels may be cited. The blood-vessels of an atrophied part, I have already said, decrease in adaptation to the part: they become less, till they can carry no more blood than is just enough to meet the diminished requirements of nutrition: and this they do, not by such muscular contraction as adapts them to a temporary decrease of function in a part, but (if one may so speak) by a diminishing growth. Moreover, when a part degenerates, its blood-vessels are likely to degenerate in the same manner. There are, I think, instances in which fatty degenerations of blood-vessels have occurred in consequence of similar change in the part that they supply. But the more interesting examples are those of primary degeneration of the blood-vessels. This has been long known in the atheromatous disease, as it was called, of the larger arteries; the true nature of which, as a fatty and calcareous degeneration of the inner, and, consecutively, of the middle, arterial coat, was discovered by Mr. Gulliver.† The descriptions of this affection by him and by Rokitsansky have left nothing unsaid that is yet known; but the observations are each year becoming more numerous and

* I have minutely described the specimens here referred to, as well as the later changes which the bones undergo, in the Pathological Catalogue of the College-Museum, vol. ii. p. 22, and vol. v. p. 7.

† Medico-Chirurg. Trans., vol. xxvi. p. 86.

interesting of similar changes in the minutest blood-vessels. Such changes are especially observable in the minutest cerebral vessels; and their importance, in relation to apoplexy, of which they seem to be the most frequent precedent, as well as for the general illustration of the minute changes on which the defective nutrition of organs may depend, will justify, I hope, my repeating the description which I wrote from the first instances in which they were observed, and has since, I think, been sufficiently confirmed.*

In the least degrees of this affection, the only apparent change of structure is, that minute, shining, black-edged particles, like molecules of oil,† are thinly and irregularly scattered beneath the outer surface of the small blood-vessels of the brain. Such a change may be seen in the vessels of portions of the brain that appear quite healthy, as well in the capillaries as in branches of both arteries and veins of all sizes, from 1-150th of an inch in diameter, to those of smallest dimension.

As the disease makes progress, the oil-particles may increase in number till the whole extent of the affected vessels is thick-set with them, and the natural structures, even if not quite wasted, can hardly be discerned. While

* Medical Gazette, vol. xlv.

† Dr. Jenner (Med. Times and Gaz., Jan. 31, 1852) has shown that these appearances of oil-particles are very closely imitated by equally minute particles similarly deposited, but which are proved to be calcareous by their solubility in hydrochloric acid. I think it very probable that what I have here described as fatty or oily matter may often be, at least in part, calcareous: we may reasonably expect this affection of the small vessels to be exactly analogous to the common fatty and calcareous degeneration of the larger arteries, although there is no generality of coincidence between them. I have also seen a pigmental degeneration of small cerebral arteries very similar to the fatty one described above.

their number thus increases, there is, also, usually, a considerable increase of the size of many of the oil-particles, and they may be seen of every size, from an immeasurable minuteness to the diameter of 1-2000th of an inch. In other places one sees, instead of this increase of scattered oil-particles, or together with it, groups or clusters of similar minute particles, which are conglomerated, sometimes in regular oval or round masses, like large granule-cells, but more often in irregular masses or patches, in the wall of a great part of the circumference of a blood-vessel.

In a single fortunately selected specimen, one may see, in different branches of a vessel, all these degrees or states of the degeneration; the less and the more thickly scattered minute oil-particles, the clusters of such particles in various sizes and shapes, and the larger particles like drops of oil.

When the degeneration has made much progress, changes in the structure, and, not rarely, changes in the shape also, of the affected blood-vessels may be observed. The chief change of structure appears to consist in a gradual wasting of the more developed proper structures of the vessels: growing fainter in, apparently, the same proportion as the disease makes progress, the various nuclei or fibres are at length altogether lost, and blood-vessels of even 1-150th of an inch in diameter appear like tubes of homogeneous pellucid membrane, thick-set with the fatty particles. The structures of the vessels are not merely obscured by the abnormal deposits: they waste and totally disappear.

The changes of shape which the vessels may at the same time undergo are various. Very commonly, the outer layer of the wall is lifted up by one or more clusters of oil-particles, and the outline of the vessel appears uneven, as if it were tuberos or knotted. Sometimes the outer or cellular coat of the vessels is for some distance raised far from the middle

coat, as if it were inflated, and the space between them contains numerous particles of oil; (but, perhaps, this raising-up of the outer coat is often produced by water being imbibed while preparing the specimen for examination.) Sometimes, but I think only in vessels of less than 1-500th of an inch in diameter, partial enlargements, like aneurismal dilatations or pouches of their walls, are found.

The vessels most liable to this disease are, I think, the arteries of about 1-300th of an inch in diameter; but it exists, generally, at the same time, in the veins of the same or of less size. As a general rule, (judging from the specimens hitherto examined), the disease decreases in nearly the same proportion as the size of the vessels, and the smallest capillaries are least, if at all, affected. But there are many exceptions to this rule; and it is not rare to find vessels of from 1-2000th to 1-3000th of an inch in diameter, having parts of their walls nearly covered with the abnormal deposits.

The principal and first seat of the deposits is, in arteries, in the more or less developed muscular or transversely fibrous coat: in veins, it is in the corresponding layer, immediately within their external fibro-cellular nucleated coat: in vessels, whether arteries or veins, whose walls consist of only a simple pellucid membrane bearing nuclei, the substance of this membrane is the first seat of the deposits. In some cases, the outer fibro-cellular coat of both arteries and veins appears to contain abundant fatty matter. But it is seldom that, in an advanced stage of the affection, any of the several coats of a blood-vessel can be assigned as its chief seat; for even in large four-coated arteries they wholly waste, and their remains appear united in a single pellucid layer, of which the whole thickness may be occupied by the deposit.

The figures represent some of the most usual appearances of the degeneration.

FIG. 7.*



FIG. 8.

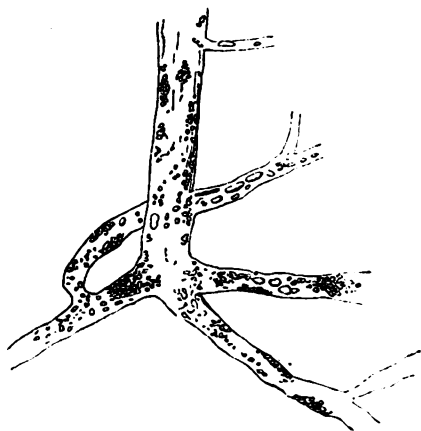
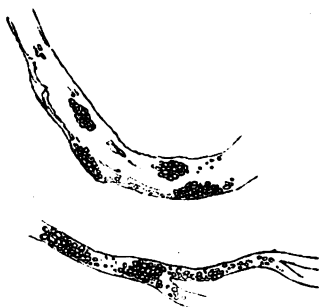


FIG. 9.



The cases in which these changes were first observed were cerebral apoplexies in which the hæmorrhage appeared certainly due to rupture of the wasted and degenerate blood-

* FIG. 7. An artery, of 1-300th of an inch in diameter, and a branch given from it, from a softened corpus striatum. Numerous oil-particles of various sizes are scattered in the muscular coat, traces of the tissue of which appear in obscure transverse marks.

FIG. 8. From the same part, a vein 1-600th of an inch in diameter, with branches from 1-1200th to 1-1800th, and portions of capillaries. Scattered oil-particles, and groups like broken irregular granule-cells, are seen in the homogeneous pellucid walls of all the vessels.

FIG. 9. A vessel of 1-600th of an inch in diameter, and another of 1-1800th, with a branch of 1-3000th of an inch. Groups and scattered oil-particles are thick-set in the simple, pellucid, membranous walls.

vessels. The probability of such an event is evident; as it is, also, that the less sudden effect of this condition of the vessels is likely to be a gradual degeneration of the parts of the brain which they supply. The relation between organs and their blood-vessels must in this respect be mutual: in the same measure, though not in the same way, as atrophy of an organ, whether wasting or degenerative, induces a corresponding atrophy of its blood-vessels, so will the imperfection of degenerate vessels lead to atrophy of the part in which they are distributed.

I suppose that the minute blood-vessels of many other parts might be often found thus degenerate, if we could examine them as easily as we can those of the brain; but I am not aware that any have been so described except those of the eye, in the cases of *arcus senilis*, to which I shall presently refer, and those of the lungs and placenta. In the lungs, Dittrich* has traced affections of the arteries which, he says, the account I have given above exactly fits, and the consequences of which, in pulmonary apoplexy, correspond with the cerebral apoplexies due to rupture of the small blood-vessels of the brain.

Many facts of exceeding interest are known concerning the degenerations of nervous tissues, but, as yet, they are rather fragments than a continuous history.

First, in relation to the causes of degeneration, two are chiefly known; namely, defect of blood, and arrested function. Cases of softening of the brain have been long recognised as the consequences of ligature, or obstructive disease, of the carotid or other large arteries; but they have received a new interest from Dr. Kirkes's discovery† of their

* Ueber den Laennec'schen Lungen-infarktus. Erlangen, 1850.

† Med-Chir. Trans., vol. xxxv.

frequency in consequence of the obstruction of healthy cerebral arteries by masses of fibrine carried into them, after being dislodged from the valves of the left side of the heart or from some part of the arterial system. In these cases, the extent of softening nearly corresponds with the range in which the branches of the obstructed artery are distributed : for, beyond the circle of Willis, the anastomosis among the cerebral arteries, like that among the cardiac, is not sufficient to carry a full supply of blood into a part from which the main stream is hindered, though generally enough to prevent the complete death or sloughing of the part.

Of the atrophy following diminished or abrogated function of nervous parts I have already mentioned examples in the shrinking of the brain in old people, in the wasting of the nerves of paralysed or fixed muscles, and in that of the optic nerve and tract in cases of blindness. To these may be added the cases observed by Dr. Waller ;* who has discovered that when a nerve is divided, its distal part, *i. e.*, the portion between the place of division and the place of distribution, the portion in which the nerve-office can be no longer exercised always suffers atrophy, wasting and degenerating. The same atrophy ensues in the whole length of any spinal nerve whose root is divided ; and in any system of nerves through which, after injury of the spinal cord, reflex actions cannot be excited. The change, in divided nerves, begins at the distal extremities of the nerve-fibres, and gradually extends upwards in the branches and trunk of the nerve ; but is repaired if the divided portions of the nerve be allowed to reunite. I need not say how great interest these facts have in relation to the anatomy and physiology of the nervous system : but it is

* Philos. Trans., 1850, Part 2 ; and more fully in the London Journal of Medicine, July 1852.

equalled by those related by Dr. Turck,* which may be used for ascertaining the functions of the several columns of the spinal cord, and their relations to the different parts of the brain, in the same manner as, by those of Dr. Waller, knowledge may be gained of the course and distribution, and of the centripetal or centrifugal office, of the several nerves. The main fact discovered by Dr. Turck is, that after diseases of parts of the brain or spinal cord there gradually ensues a softening, as by atrophy, of those tracts or columns of the cerebro-spinal axis, through which, in health, impressions were habitually conveyed from the diseased part. The same general truth is illustrated by both these series of observations; namely, that nerve-fibres, through which, from whatever cause, nerve-force can be no longer exercised, are gradually atrophied. The atrophy took place very quickly in the frogs that were the subjects of Dr. Waller's experiments: commencing in young frogs, during the summer, in from three to five days, and being completed in from twenty to thirty days. But, in the human subject, the process, reckoned by the observations of Turck, and those in which I have examined nerves atrophied in paralysed muscles, is much slower. Changes in the spinal cord are not, he says, discernible in less than half a year after the apoplexy or other affection of the brain of which they are the consequence.

The changes in the nerve-fibres thus atrophied are minutely described by Dr. Waller. At first, transverse lines appear in the intratubular substance, indicating its loss of continuity; then it appears as if divided into round or oblong coagulated masses, as if its two component materials were mingled; then these are converted into black granules,

* Ueber secundäre Erkrankung einzelner Rückenmarkstränge. Wien, 1851.

resisting the action of acids and alkalies ; and, finally, these granules are slowly and imperfectly eliminated.

In the atrophies of the brain and spinal cord, whether from obstructed circulation or from hindered function, the chief changes that are observed are, the liquefaction or softening of the whole substance, the breaking-up of the nerve-fibres, and the production of abundant granule-cells or masses, and free-floating granules. The exact nature of the change on which the softening of the substance depends is not yet known ; neither can we be sure of the origin of the granule-cells. They are very like those commonly formed in the granular or fatty degeneration of various cells of both normal and morbid origin : but, produced as they are in parts of the brain and cord in which no cell-structures naturally exist, (for they may be as abundant in the white substance as in the grey), we have yet, I believe, to trace the source and method of their formation.

Their likeness to the granule-cells of recognised fatty degenerations might be thought sufficient to justify the arrangement of the softenings of nerve-substance with the rest of that great division of atrophies : but the concurrence of so peculiar a softening of texture, and the similar examples of softening or liquefaction, concurrent with the formation of granule-cells, which are observed in numerous morbid growths, incline me to suggest that, for the present, it will be better to speak of these changes as liquefactive degenerations.

The last example of atrophy of which I will speak is that which is manifested in the Arcus senilis,—the dim greyish-white arches or ellipse seen near the borders of the cornea in so many old persons. Its nature, as a true fatty degeneration, consisting in the accumulation of minute oil-drops in the proper tissue of the cornea, was discovered and is

fully described by Mr. Canton.* By his and others' † investigations, it has also acquired a larger interest, in being found the frequent concomitant and sign of more widely extended degenerations that are not within sight during life. Thus, it is commonly associated with fatty or calcareous degeneration of the ophthalmic artery; with fatty degeneration of the muscles of the eye-ball; and, especially in old persons, with fatty degeneration of the heart and many other organs. In short, the arcus senilis seems to be, on the whole, the best indication that has been yet found of proneness to an extensive or general fatty degeneration of the tissues. It is not, indeed, an infallible sign thereof; for there are cases in which it exists with clear evidences of vigour in the nutrition of the rest of the body; and there are others in which its early occurrence is due to defective nutrition consequent on purely local causes, such as inflammatory affections of the choroid, or other parts of the eye: but, allowing for these exceptions, it appears to be the surest, as well as the most visible, sign and measure of those primary degenerations which it has been the chief object of the last two lectures to describe.‡

* Observations on the Arcus senilis, in the *Lancet*, 1850 and 1851.

† Especially Drs. Quain, Williams, and Virchow (*Archiv*, B. iv. p. 288).

‡ The degenerations of organs not described in the lectures may be studied by the following references:—

Arteries, Testicles, Lungs, and Liver: Gulliver, in *Med.-Chir. Trans.*, xxvi. p. 86.

Liver: Bowman, in *Lancet*, 1841-2, vol. i. p. 560.

Kidney: Johnson, in *Med.-Chir. Trans.*, xxix. p. i.; with Appendix in xxx. p. 182; Simon, in *Med.-Chir. Trans.*, xxx. p. 141; Virchow, in his *Archiv*, B. iv. p. 264, et seq.; and Gairdner, *Pathology of the Kidney*, Edinb. 1848.

Colourless blood-cells, various Epithelial cells, Cartilage-corpuscles, Nerve-cells: Virchow, in his *Archiv*, i. p. 144.

Lungs: Rainey, in *Med.-Chir. Trans.*, vol. xxxi. p. 297.

[Placenta:

Placenta : Barnes, in *Med.-Chir. Trans.*, xxxiv. p. 183.

Placenta, Decidua, and other tissues of the Uterus, as well as the Muscular : Kilian, as quoted at p. 131.

Cartilage : Redfern, "Anormal Nutrition in the Articular Cartilages," 1850 ; and Virchow, in his *Archiv*, B. iv. p. 289.

Numerous calcareous degenerations : Dusseau, *Het Beenweefsel en Verbeeningen*, Amsterdam, 1850.

Pigmental degenerations : Virchow, in his *Archiv*, B. i.

The chief general histories of degenerations are by Rokitansky, *Pathol. Anat.* ; C. J. B. Williams, *Principles of Medicine* ; and Virchow, in the places cited above, and in his *Archiv*, B. iv. p. 394.

A remarkable series of instances of fatty degeneration of voluntary muscles has been lately communicated to the Medico-Chirurgical Society by Dr. Meryon, and will be published, I believe, in the 35th volume of the *Transactions*.

The degenerations of products of disease will be described in future lectures.

LECTURE VII.

GENERAL CONSIDERATIONS ON THE REPAIR AND REPRODUCTION OF INJURED AND LOST PARTS.

AMONG the general considerations that may be suggested by the preceding lectures, none, perhaps, is more worthy of earnest thought, than that of the capacity of adaptation to the variety of their circumstances, which is displayed by the several parts of the body. Each part may be said to be conformed, in its first construction, to a certain standard of measure, weight, and power, by which standard it is adjusted to the other parts of the whole organism. The first perfection of the economy is in the justness with which its several parts are thus balanced in their powers; and the mutual adaptation thus established is continued, in ordinary life, by the nutrition of each part being regulated according to a law of direct proportion to the quantity of work that each discharges. But when the external conditions of life vary, and require, for the maintenance of health, varying amounts of function to be discharged by one or more parts; and, still more, when disease disturbs the functional relations of any part to the rest; then each part displays a capacity of adaptation to the new conditions in which it is placed: each can assume a less or greater size and weight; each can acquire a less or more powerful tissue; each can thus rise above, or descend below, its standard of power.

This capacity of adaptation is shown in a yet more

remarkable manner in the recovery of parts from the effects of injuries and diseases. It is surely only because it is so familiar, that we think lightly, if at all, of the fact that living bodies are capable of repairing the effects of injury, and that in this capacity they prove themselves adapted for events of which it is not certain whether they will ever occur to them or not. The exact fitness of every part of a living body for its present office, not as an independent agent, but as one whose work must be done in due proportion with many others concurring in operation with it, is a very marvellous thing: but it seems much more so, that in the embryo, each of these parts was made fit for offices and relations that were then future: and yet more marvellous than all it seems, that each of them should still have capacity for action in events that are not only future, but uncertain; that are indeed possible, yet are in only so low a degree probable, that if ever they happen they will be called accidents.

Let us have always in mind this adaptation of the living body to future probabilities, while we consider the physiology of repair. If it be fairly weighed, every part of the process of repair will be an argument of divine design; and such an argument as cannot be impugned by the suspicion that the events among which each living thing is cast have determined its adaptation to them: for all the adaptations here noted prove capacities for things future, and only not improbable.

And let us also keep in view how the reparative processes may illustrate the laws of ordinary nutrition; and especially observe that they furnish evidence of the nature of the formative force exercised in the complete organism. I mentioned in a former lecture (p. 60) that, in many instances of repair and reproduction, the formation of the new replacing structures cannot be ascribed

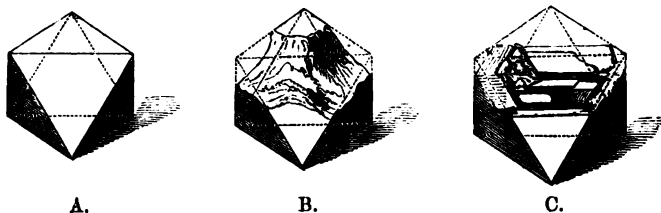
to an assimilative force, or to the development of tissue-germs derived from the injured or lost parts. The completeness of repair after injury, and the extent to which it is sometimes accomplished, become thus most striking evidences of the principle that the formative force, and those that co-operate with it, are, in the completed organism, the same and continuous with those which actuated the formation of the original tissues, in the development of the germ and embryo. There is in every considerable process of repair a re-making of a part: and the new materials assume the specific form and composition of the part that they replace, through the operation of no other, or otherwise directed, force, than that through which that part was first made. For, in all grave injuries and diseases, the parts that might serve as models for the repairing materials to be assimilated to, or as tissue-germs to develop new structures, are lost or spoiled; yet the effects of such injury and disease are recovered from, and the right specific form and composition are regained. In all such cases, the reproduced parts are formed, not according to any present model, but according to the appropriate specific form; and often with a more strikingly evident design towards that form as an end or purpose, than we can discern in the natural construction of the body.

Moreover, it will be observed in the instances of repair of injury, even more plainly than in the maintenance of the body in the successive ordinary stages of its life, that the law of formation is at each period of life the same;—that every part is formed after the same method as was observed in the corresponding part of the parent at the same period of life. Thus, when, in an adult animal, a part is reproduced after injury or removal, it is made in conformity, not with that condition which was proper to it when it was first formed, or in its infantile life, but with

that which is proper according to the time of life in which it is reproduced ; proper, because like that which the similar part had, at the same time of life, in members of former generations. In the reproduction of the foot or the tail of the lizard, they grow, as it were, at once into the full dimensions proper to the part, according to the age of the individual. Spallanzani expressly mentions this : — that when a leg is cut from a full-grown salamander, the new leg and foot are developed, as far as form and structure are concerned, just as those of the larva were ; but as to size, they from the beginning grow and are developed to the proper dimensions of the adult. The power, therefore, by which this reproduction is accomplished, would seem to be, not the mere revival of one which, after perfecting the body, had lapsed into a dormant state, but the self-same power which, before the removal of the limb, was occupied in its maintenance by the continual mutation of its particles, and is now engaged, with more energy, in the reconstruction of the whole.

The ability to repair the damages sustained by injury, and to reproduce lost parts, appears to belong, in some measure, to all bodies that have definite form and construc-

FIG. 10.



tion. It is not an exclusive property of living beings ; for even crystals will repair themselves when, after pieces

have been broken from them, they are placed in the same conditions in which they were first formed.

The diagram represents a series of casts made from a crystal with which I imitated the experiments of Jordan.* A large piece was broken off an octohedral crystal of alum (A). Before the fracture it was perfect in its form, except at one small pit on its surface, where it had what (writing of animal physiology) might be called a congenital defect. Thus broken (B) it was placed again in the solution in which it had been formed, and after a few days its injury was so far repaired as it appears in the figure C. The whole crystal had increased, but the increase on its broken surface was proportionally so much greater than on any other, that the perfect octohedral form was nearly regained. The little congenital defect, also, was completely healed. In a few days more the whole crystal would have been as if it had suffered no injury.

I know not what amount of mutual illustration, if any, the repair of crystals and of living bodies may afford; but, in any case, we may trace here something like an universal property of bodies that are naturally and orderly constructed: all, in favourable circumstances, can repair at least some of the damages to which they are liable from the violence of external forces.

But, to speak only of the repair and reproduction that occur in the several orders of the animal kingdom: among these they exist in singularly different degrees, and in such as can be only partially included in rules or general expressions. The general statement sometimes made, that the reparative power in each species bears an inverse ratio to its position in the scale of animal life, is certainly not proved;

* Müller's Archiv, 184', p. 46.

and many instances are contrary to it : such as the great reparative power possessed by the Triton and other lizards, and the apparently complete absence of it in the perfect insects. Rather, the general rule which we may expect to find true, and for which there is already much evidence, may be that the reparative power bears an inverse proportion to the amount of power consumed in the development and growth of the individual, and in its maintenance in the perfect state.

Our ideas of the consumption of power in the organization of matter, are, perhaps unavoidably, very vague : yet are there facts enough to prove that the power which can be exercised in a germ is limited, so that the capacity of assuming the specific organic form cannot be communicated to an indefinite quantity of matter ; and there are also enough to justify the expression, that the power, thus limited, is in some measure consumed, 1st, in the development of every new structure, and, 2dly, in a less measure, in the growth and maintenance of those already formed.

Thus, first, it appears constantly true, that the reparative power is greater in all parts of the young than in those of the older individuals of all species. Even when we compare individuals that have all attained their highest development and growth, this rule seems to be true. We know it from general observations of the results of similar injuries and diseases in persons of different ages : numerous as the exceptions may be, the general rule seems true. And it is yet more evidently proved in the case of some lower animals. Spallanzani mentions it in regard to the reproduction of the tail of the tadpole. The quickness with which the work of reproduction is both begun and perfected was always, in his experiments, in an inverse ratio to the age. He says the same for the reproduction of the legs of salamanders,

and it is only in the young, among frogs and toads, that any reproduction of the limbs will take place. So, too, in experiments on the repair of fractures, the union of tendons and the like, in the mammalia, one may see abundant evidence that the vigour and celerity of the process are in an inverse proportion to the animal's age. There is, indeed, some reason to believe, that in the very early period of embryonic life, a true reproduction of parts of limbs may take place even in the human species. Not to speak of the possibility that supernumerary members may be formed in consequence of accidental fission of the budding limbs of the embryo, there are cases in which fingers are found on the stumps of arms in such circumstances as justify the belief, that after a limb had been accidentally amputated in the uterus, these had been produced on its remaining portion.*

All these facts agree well with the belief that the formative power is gradually diminished in the acts of organizing matter for the maintenance of the body ; and the difference between the completeness of repair in children and that in adults appears so much greater than the difference in adults of different ages, that it is probable the formative power is more diminished by growth than by mere maintenance.

But, secondly, it seems that the capacity for the repair or reproduction of injured parts is much more diminished by development, than by growth or maintenance of the body ; *i. e.*, much more by those transformations of parts by which they become fitted for higher offices, than by the multiplication or maintenance of those that are already perfect in their kind and function. In other words, to improve a

* See a paper by Dr. Simpson, in the London and Edinburgh Monthly Journal, Jan. 1848.

part requires more, and more perfect, formative power, than to increase it does.

This, as a general principle, is exemplified in many instances. In the greater part of congenital malformations we find arrest of development, but no hinderance of growth; as a heart, in which a septum fails to be developed, yet grows to its full bulk. If tadpoles be excluded from due light and heat, their development will be much retarded, but their growth will be less checked: in other words, the conditions of nutrition which are enough for growth are not sufficient for development. When a part is, without disease, unduly supplied with blood, it may grow beyond its normal size, but it is never developed beyond its normal structure: that which is sufficient for increase of growth, is not enough for an advance in development. Again, in the miscalled cultivation and improvement of flowers, growth is increased, but development is hindered; and an excess of coloured leaves is formed, instead of the due number of male and female organs. In an old ulcer or a sinus, cells may be continually reproduced, maintaining or even increasing the granulations, yet they will not develop themselves into cellular tissue and cuticle for the healing of the part. And so, lastly, even when repair and reproduction have gone far towards their ultimate achievement, that which takes a longer time, and oftener fails, is the improvement, the perfecting, of the new material, by its final development. This is observed in all cases of reproduced limbs, and even in ordinary scars.

These facts (and there are many others like them) seem to justify the expression that, not only more favourable conditions, but also a larger amount of organizing force, are expended in development than in growth, or maintenance; and that the reparative power bears an inverse ratio to the

amount of force already expended in these processes. If it be so, we might expect that in each species, in its perfect state, the reparative power might be measured by the degree of likeness between the embryonic and the perfect form, structure, and composition.

There are many apparent exceptions to such a rule, especially in the Asteriæ, which, though constructed through manifold metamorphoses, have great capacity of restoring detached rays; yet it is consistent with such a rule that the highest amount of reparative power exists in those lowest polypes in which the materials of the germ-mass are least transformed, but are multiplied, and, as it were, grouped into the shape of their bodies. In the *Hydra viridis*, and *Hydra fusca*, it seems literally true that any minute portion derived from the germ-mass, may, after being separated from the perfect body, reproduce the perfect form. This is the general truth of the numerous experiments performed on *Hydræ* by Trembley, Roesel, and others. They have been so often quoted, that I need not do more than mention the greatest instances of reproductive power that they showed.

Trembley cut an *Hydra* into four pieces: each became a perfect *Hydra*; and, while they were growing, he cut each of these four into two or three. These fractions of the quarters being on their way to become perfect, he again divided these, and thus he went on, till from the one *hydra* he obtained fifty. All these became perfect; he kept many of them for more than two years, and they multiplied by their natural gemmation just as much as others that had never been divided. Again, he cut similar polypes longitudinally, and in an hour or less each half had rolled itself, and seamed up its cut edges, so as to be a perfect *Hydra*. He split them into four; he quartered them; he cut them into as many pieces as he could; and nearly every piece

became a perfect Hydra. He slit one into seven pieces, leaving them all connected by the tail, and the Hydra became seven-headed, and he saw all the heads eating at the same time. He cut off the seven heads, and, hydra-like, they sprang forth again. And even the fabulist dared not invent such a prodigy as the naturalist now saw. The heads of the Lernæan Hydra perished after excision: the heads of this Hydra grew for themselves bodies, and multiplied with as much vigour as their parent-trunk.

Now these instances may suffice to show not only the great capacity of reproduction in the lowest polypes, but, also, that in them the process of reproduction after injury confounds itself with that of their natural generation by gemmation, or, as it probably more rarely happens, by spontaneous fission. We cannot discern a distinction between them; and there are facts which seem to prove the identity of the power which operates in both. Thus, in both alike, the formative power is limited according to the specific characters of the Hydra: immense as the power of increase is which may be brought into action by the mutilations of the Hydra, yet that power cannot be made to produce an Hydra of much more than ordinary size, or to raise one above its ordinary specific characters. And, again, the identity of the power is shown in this, that the natural act of gemmation retards that of reproduction after injury. Trembley particularly observes, that when an Hydra, from which the head and tentacula had been cut off, gemmated, the reproduction of the tentacula was retarded soon after the gemmule appeared.

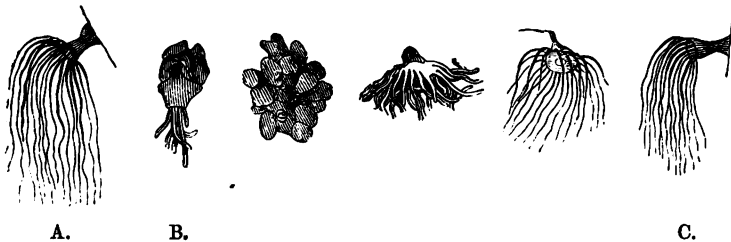
Many other species manifest this coincidence of the power of propagating by gemmation or fission, and of reproducing large portions of the body, and even of reconstructing, from fragments, the whole body. Among them, as chief examples, are the Actiniæ, which after bisection

form two perfect individuals; and the *Holothuriæ*, which, as Sir J. G. Dalyell has observed, when hurt or handled, will eject all their viscera, leaving their body a mere empty sac, and yet in three or four months will have all their viscera regenerated. And to these may be added, from among the *Anellata*, the young *Nereids*, and those species of *Nais*, on which Bonnet, Spallanzani, and others, made their experiments; experiments of which the climax seemed to be achieved when a *Nais* was cut by M. Lyonnet into thirty or forty separate pieces, and there were produced from those fragments as many perfect individuals.

Among the instances of greatest capacity of repair, some observed by Sir J. G. Dalyell* seem to illustrate, in a remarkable manner, the general laws of the reparative processes in even the higher animals; and especially the gradual improvement of the repairing part, by which, at length, the effects of injury may be quite annulled.

In the *Hydra Tuba*, the species of which he traced that

FIG. 11.



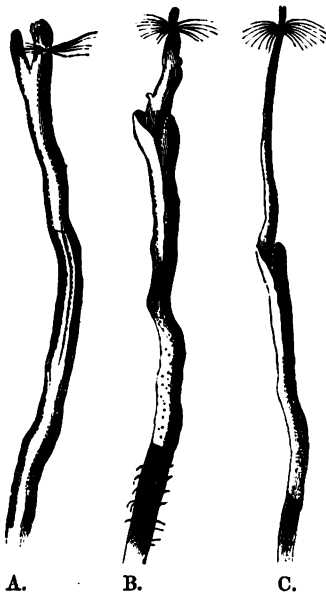
marvellous development into *Medusæ*, he found that when cut in halves, each half may regain the perfect form; but this perfect form is regained only very slowly, and, as it

* *Rare and Remarkable Animals of Scotland*, vol. i.

were, by a gradual improvement of parts that are at first ill-formed. The sketch, copied from his plate, shows the succession of forms marking these stages of improvement in the stump, or attached part of an Hydra Tuba (A), from which the distal half with the tentacula was cut off.

Through these forms, commencing at B, into which the attached half of A was first changed, the perfect state of an Hydra was at length reached; as at C. The fact may possibly be explained (as he suggests) by the mutilation having disturbed the progress of the Hydra in its development of young Medusæ; for the experiment was made in March, nearly at the

FIG. 12.



time when the series of changes should have commenced. But, if I may venture not to accept the suggestion of so admirable an observer, I should suspect rather that this is an instance of gradual recovery of perfection, such as we see more generally in the repair of injuries and diseases in the higher animals.

He has noticed something of the same kind, and more definite, in the Tubularia indivisa; one of his experiments on which is here illustrated. A fine specimen was cut near its root, and after the natural fall of its head, the summit of its stem was cloven. An imperfect head was first produced, at right angles to the stem, from one portion of the cleft (A); after its fall, another and more nearly perfect one was regenerated, and, as it grew, improved yet more (B). A third appeared, and then

a fourth, which was yet more nearly perfect, though the stem was thick, and the tentacula imperfect. The cleft was almost healed; and now a fifth head was formed, quite perfect (C); and after it, as perfectly, a sixth and a seventh head. All these were produced in fifteen months.

The lower half of this specimen had been cut off four months after the separation of the stem. Its upper end bore—first, an abortive head; then, secondly, one which advanced further in development; a third, much better; and then, in succession, other four, which were all well formed.

The upper portion of this lower half of the stem now showing signs of decay, a portion was cut from its lowest part, and further manifested the reproductive power of the stem; for three heads were produced from the upper end of the piece cut off, and four from the lower end of the upper piece which had seemed to be decaying. In 550 days this specimen had grown twenty-two heads.

Now, I cannot but think that we have, in these instances of gradual recovery from the effects of injury, a type of that gradual return to the perfect form and composition which is noticed in the higher animals. Our theory of the process of nutrition leads us to believe that, in the constant mutation of particles in nutrition, those elements of the blood, or of any structure, that have been altered by disease, in due time degenerate or die, and are cast-off or absorbed; and that those which next succeed to them partake, through the assimilative force, of the same morbid character; but that, every time of renewal, the new particles approach a step nearer to the perfect state. Thus, as it were, each generation of new particles is more nearly perfect, till all the effects of the injury or the disease are quite obliterated. Surely, in the gradual recovery of perfection by these

polypes, we have an apt illustration of the theory ; one which almost proves its justice.

The power of reconstructing a whole and perfect body, by the development of a fragment, is probably limited to the species that can propagate by spontaneous fission or gemmation, or that increase their size, as some of the Anelata do, by the successive addition of rings that are developed after the manner of gemmules from those that precede them. Where this power is not possessed, there, whatever be the position of the species in the animal scale, the reparative power appears to be limited to the reproduction of lost members ; such as legs, claws, a part of the body, the head, an eye, the tail, and the like. Within this limit, the rule seems again to hold good, that the amount of reparative power is in an inverse ratio to that of the development, or change of structure and mode of life, through which the animal has passed in its attainment of perfection, or on its way thitherward.

Here, however, even more than in the former cases, we need, not perhaps more experiments, but experiments on a larger number of species. It appears generally true, that the species whose development to the perfect state is comparatively simple and direct, have great reparative powers ; while many, at least of those in which the development is with such great changes of shape, structure, and mode of life, as may be called metamorphosis, retain in their perfect state scarcely any power for the repair of losses. Yet we want more instances of this ; and especially, it were to be wished that we had the results of experiments upon the lowest animals that pass through such metamorphoses ; *e. g.* on the *Hydra tuba*, not only in its *Hydra* state, but in all the changes that succeed, till it attains its complete Medusal form.

In the absence of such evidence as experiments of this kind might furnish, the best examples of the rule are furnished by the experiments of Mr. Newport. They show that among the insects, the reparative power, in the complete state, is limited to the orders in which that state is attained by a comparatively simple and direct course of development; as the Myriapoda and Phasmidæ, and some of the Orthoptera. These can reproduce their antennæ, and their legs, after removal or mutilation; but their power of reproduction diminishes as their development increases. Even in the Myriapoda, whose highest development scarcely carries their external form beyond that of the larvæ of the more perfect insects, such reparative power apparently ceases, when, after the last casting of their integuments, their development is completed.

In the higher hexapod insects, such reproduction has been seen in only the larval state; none of them, in its perfect state, can reproduce an antenna, or any other member. The Myriapoda, then, are, in their reparative power, equal to the larvæ of the higher insects, and nearly all the power for formation which these manifest, appears to be exhausted in the two later metamorphoses.

The case is the stronger, as illustrating the expenditure of power in metamorphoses, when the higher insects are compared with the Arachnida; for in these, which attain their perfect state through more direct development, the reparative power remains equal to the reproduction of limbs and antennæ. A yet stronger contrast is presented between the higher insects and the several species of salamander, in which so profuse a reproduction of the limbs has been observed; for though they be so much higher in the scale of animal life, yet the amount of change in external form and habits of life, through which they pass, in their develop-

ment from the embryo to the perfect state, appears less than that accomplished in the metamorphoses of insects.

Many instances, besides those which I have cited, appear to support this rule, that the reparative power, in each perfect species, whether it be higher or lower in the scale, is in an inverse proportion to the amount of change through which it has passed in its development from the embryonic to the perfect state. And the deduction we may make from them is, that the powers for development from the embryo are identical with those exercised for the restoration from injuries: in other words, that the powers are the same by which perfection is first achieved, and by which, when lost, it is recovered.

This is, again, generally confirmed in the instances of the Vertebrata; but of the repair in these, or at least in the highest of them, I shall have to speak so exclusively in the future lectures, that I will now only say that, in man and other mammalia, a true reproduction after loss or injury seems limited to three classes of parts:—

1. To those which are formed entirely by nutritive repetition; such as the blood and the epithelia.

2. To those which are of lowest organization, and (which seems of more importance) of lowest chemical character; as the gelatinous tissues, the cellular and tendinous, and the bones.

3. To those which are inserted in other tissues, not as essential to their structure, but as accessories, as connecting or incorporating them with the other structures of vegetative or animal life; such as nerve-fibres and blood-vessels.

With these exceptions, injuries or losses in the human body are capable of no more than repair, in its most limited sense; *i. e.* in the place of what is lost, some lowly orga-

nized tissue is formed, which fills up the breach, and suffices for the maintenance of a less perfect life.

I may seem in this, as in some earlier lectures, to have been discussing doctrines that can hardly be applicable to our daily practice, and with illustrations drawn from objects in which surgeons may have but little interest. Let me, then, if only in apology, refer to some of the considerations which are suggested by studies such as these. Let me, first, express my belief that, if we are ever to escape from the obscurities and uncertainties of our art, it must be through the study of those highest laws of our science, which are expressed in the simplest terms in the lives of the lowest orders of creation. It was in the search after the mysteries—that is, after the unknown highest laws—of generation, that the first glance was gained of the largest truth in physiology; the truth of the development of ova through partition and multiplication of the embryo-cells. So may the study of the repair of injuries sustained by the lowest polypes lead us to the clearer knowledge of that law, in reliance upon which alone we dare to practise our profession; the law, that lost perfection may be recovered by the operation of the powers by which it was once achieved. Already, in the facts that I have quoted from Sir Graham Dalyell, we seem to have the foreshadowing of those through which the discovery may be made.

Then, let us not overlook those admirable provisions, which we may find in the lives of all that breathe, against injuries that, but for these provisions, would too often bring them to their end before their appointed time, or leave them mutilated to finish a painful and imperfect life. We are not likely to undervalue, or to lose sight of, the design of all such provisions for our own welfare. But we may better appreciate these, if we regard them as only of the same kind as those

more abundantly supplied to creatures whom we are apt to think insignificant: indeed, so abundantly, that, as if with a consciousness of the facility of repair, self-mutilation is commonly resorted to for the preservation of life. When the Ophiuræ, or any of the brittle Star-fishes, break themselves to fragments, and disappoint the grasp of the anxious naturalist, they probably only repeat what they are instinctively taught to do, that they may elude the jaws of their more ravenous enemies. But death would be much better than such mutilation, if their rays could not be reproduced almost as easily as they can be rejected. The experimentalist, too, who cuts off one or the other end of any of the Anellata, perhaps only puts them to a necessity to which they are liable from the attacks of their carnivorous neighbours. Almost defenceless, and so easily mutilated, their condition, were it not for their faculty of reproduction, might be more deplorable than that of any other creature; and even their existence as species might have been endangered long ago. It would almost seem as if the species that have least means of escape or defence from mutilation were those on which the most ample power of repair has been bestowed; an admirable instance, if it be only generally true, of the beneficence that has provided for the welfare of even the least (as we call them) of the living world, with as much care as if they were the sole objects of the Divine regard.

Lastly, if I may venture on so high a theme, let me suggest that the instances of recovery from disease and injury seem to be only examples of a law yet larger than that within the terms of which they may be comprised; a law wider than the grasp of science; the law that expresses our Creator's will for the recovery of all lost perfection. To this train of thought we are guided by the remembrance that the healing of the body was ever chosen as the fittest

emblem of His work, whose true mission was to raise man's fallen spirit and repair the injuries it had sustained; and that once, the healing power was exerted in a manner purposely so confined as to advance, like that which we can trace, by progressive stages to the complete cure. For there was one, upon whom, when the light of Heaven first fell, so imperfect was his vision, that he saw, confusedly, "men, as trees walking;" and then, by a second touch of the Divine Hand, was "restored, and saw every man clearly." Thus guided by the brighter light of revelation, it may be our privilege, while we study the science of our healing art, to gain, by the illustrations of analogy, a clearer insight into the Oneness of the plan by which things spiritual and corporeal are directed. Even now, we may trace some analogy between the acts of the body and those of man's intellectual and moral nature. As in the development of the germ, so in the history of the human spirit, we may discern a striving after perfection; after a perfection, not viewed in any present model (for the human model was marred almost as soon as it was formed), but manifested to the enlightened Reason in the "Express Image" of the "Father of Spirits." And so, whenever, through human frailty, amid the violences of the world, and the remaining "infection of our nature," the spirit loses aught of the perfection to which it was once admitted, still its implanted Power is ever urgent to repair the loss. The same power, derived and still renewed from the same Parent, working by the same appointed means, and to the same end, restores the fallen spirit to nearly the same perfection that it had before. Then, not unscarred, yet living—"fractus sed invictus"—the Spirit still feels its capacity for a higher life, and presses to its immortal destiny. In that destiny the analogy ends. We may watch the body developing into all its marvellous perfection

and exact fitness for the purpose of its existence in the world; but, this purpose accomplished, it passes its meridian, and then we trace it through the gradual decays of life and death. But, for the human Spirit, that has passed the ordeal of this world, there is no such end. Emerging from its imprisonment in the body, it soars to the element of its higher life: there, in perpetual youth, its powers expand, as the vision of the Infinite unfolds before it; there, in the very presence of its Model, its Parent, and the Spring of all its Power, it is "like Him, for it sees Him as He is."

LECTURE VIII.

THE MATERIALS FOR THE REPAIR OF INJURIES.

IN the present lecture I propose to give a general account of the materials employed for the repair of some of the injuries inflicted on the human body.

I hope I do not err in thinking that the most advantageous mode of treating this subject will be to confine myself to that class of injuries which may be called visible breaches of continuity; such as wounds and fractures. For, in regard to the recovery from diseases, our knowledge of the effects of any disease seems, as yet, too imperfect for us to trace the stages by which the morbid state reverts to that which is healthy. We may be sure it is in conformity with the same general laws as those of recovery from injury, and almost sure that it is by the gradual improvement of the particles that in succession replace those altered by disease. But the whole details of the process have yet to be discovered.

Even within the narrower field of the repair of breaches of continuity, I must yet assign to myself a closer limit. A future lecture will be devoted to the healing of fractures; in this, therefore, I shall speak almost exclusively of the healing of divided soft parts; and I shall take, as the chief and typical examples, the repairs of wounds made in operations. References to the healing of other injuries may,

however, be made by the way, and for collateral illustration.

Modern surgery has shown how right Mr. Hunter was, when, in the very beginning of his discussion concerning the healing of injuries, he points out, as a fundamental principle, the difference between those two forms of injuries of which one is subcutaneous, the other open to the air. He says : " The injuries done to sound parts I shall divide into two sorts, according to the effects of the accident. The first kind consists of those in which the injured parts do not communicate externally, as concussions of the whole body, or of particular parts, strains, bruises, and simple fractures, which form a large division. The second consists of those which have an external communication, comprehending wounds of all kinds and compound fractures."* And then, he says, " The injuries of the first division, in which the parts do not communicate externally, seldom inflame ; while those of the second commonly both inflame and suppurate."

In these sentences Mr. Hunter has embodied the principle on which is founded the whole practice of subcutaneous surgery ; a principle of which, indeed, it seems hardly possible to exaggerate the importance. For, of the two injuries inflicted in a wound, the mechanical disturbance of the parts, and the exposure to the air of those that were covered, the exposure, if continued, is the worse. Both are apt to excite inflammation ; but the exposure excites it most certainly, and in the worse form ; *i. e.*, in the form which most delays the process of repair, and which is most apt to endanger life. Abundant instances

* Works, vol. iii. p. 240.

of this are shown in the difference between a simple and a compound fracture, though the former may have been produced by the greater violence ; or, between a simple fracture, even with much violence, extending into a joint, and an open wound, never so gently made into one. Or, for parallel instances, one may cite the rarity of suppurations after even extensive ecchymoses, and their general occurrence when wounds are left open.

I had frequent occasion to observe these differences, in a series of experiments made for the illustration of the healing of divided muscles and tendons. Some of these were divided through open wounds, and some by subcutaneous section ; and the recital of a single experiment may afford a fair example of the difference of results that often ensued. In the same rabbit, the tibialis anticus and extensor longus digitorum were divided on the right side with a section through the skin ; on the left, with a subcutaneous section, through a small opening. Twelve days afterwards the rabbit was killed. The wound on the left side was well repaired, and with comparatively little trace of inflammation : the gap on the right was closed in with a scab, and an imperfect scar, but under these was a large collection of pus, and no trace of a reparative process. The contrast is the stronger, because in all these cases there is, unavoidably, more mechanical violence inflicted in the gradual subcutaneous division than in the simple open wound. And, it must be added, that a speedy closure of the external wound made in an open section may bring the case into more favourable conditions than those of a subcutaneous wound made with more violence. This, also, I saw in some of the experiments : a clumsy subcutaneous division of one Achilles-tendon excited great inflammation about it ; while the open section of the other tendon in the same rabbit was quickly and well repaired, if the external wound

had been speedily united, and had sufficiently soon converted the open into a subcutaneous injury.

Still, what Mr. Hunter said is true, especially in wounds in our own bodies: subcutaneous wounds seldom inflame; open wounds generally both inflame and suppurate. It will be a principal object of this lecture to show something like an anatomical reason for this difference, in the fact that the materials produced for the repair of open wounds are not usually the same, or, at least, do not develop themselves in the same manner, as those for the repair of closed or subcutaneous ones. The physiological and nearer reason is probably to be discovered in the influence of oxygen abnormally admitted to the tissues, and producing in them such effects as are more nearly traced in the phenomena of inflammation, and will be described in future lectures.

Before speaking of the materials for repair, I must briefly state that the healing of open wounds may be accomplished by five different modes: namely, 1. By immediate union; 2. By primary adhesion; 3. By granulation; 4. By secondary adhesion, or the union of granulations; 5. By healing under a scab. The repair of subcutaneous wounds may be effected by immediate union, but is generally accomplished by connection, or the formation of bonds of union between the divided and retracted parts. Very rarely it is effected by means of granulations without suppuration.

Of these modes, which I hope to describe hereafter in detail, it is the peculiarity of the first, or process of immediate union, that it is accomplished by the mere re-union or re-joining of the divided parts, without the production or interposition of any new material. In all the others, new material is produced and organized. This process of

immediate union corresponds with what Mr. Hunter called "union by the first intention." It is not the same as that which, in modern surgery, is called union by the first intention; for that is the same as Mr. Hunter named "union by adhesion," or "by the adhesive inflammation," and is effected, as he described it, by the organization of lymph interposed between two closely approximated wounded surfaces. Mr. Hunter maintained that union by the first intention is effected by means of the fibrine of the blood extravasated between the surfaces of the injured part, which fibrine, there coagulating, adheres to both the surfaces, becomes organized, and forms a vascular bond of union between them.* Doubtless, Mr. Hunter was, in this, in error; but, as the blood extravasated in wounds is not without influence on their repair, I will endeavour to state the several modes in which it may, when thus extravasated, be finally disposed of.

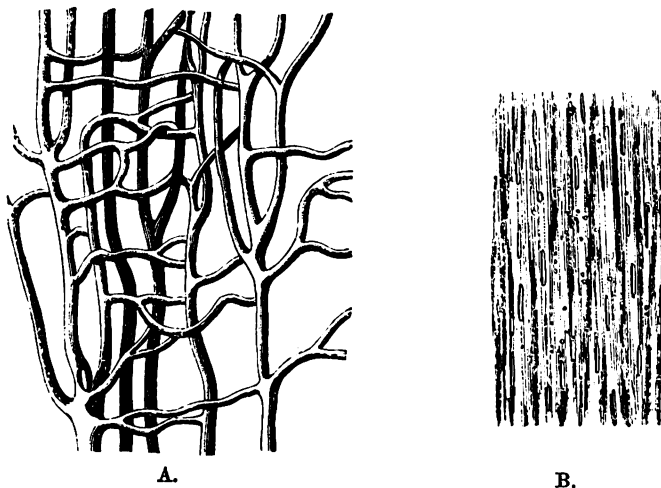
There are ample evidences for believing that masses of effused, or stagnant and coagulated, blood may be organized; *i. e.* may assume the characters of a tissue, and may coalesce with the adjacent parts and become vascular. These evidences include cases of blood effused in serous sacs, especially in the arachnoid; of clots in veins organizing into fibrous cords, or, after less organization, degenerating into phlebolithes; clots organising into tumours in the heart and arteries; and the clots so organized above ligatures on arteries as to form part of the fibrous cord by which the obliterated artery is replaced. These last cases afford most conclusive evidence, because they have been very carefully investigated in a series of experiments and microscopic observations, by Dr. Zwicky.†

* Works, vol. iii. 253.

† Die Metamorphose des Thrombus. Zurich, 1845.

In 1848, I had the opportunity of examining a specimen which, more fully than any other I had seen, confirmed Zwicky's account of the mode in which blood-clots become organized. It supplied, too, some facts which appear important to the present subject. It was obtained from an insane person, by my friend Mr. Holmes Coote. A thin layer of pale blood-coloured and ruddy membrane lined the whole internal surface of the cerebral dura mater, and adhered closely to it. Its colour, the existence of patches of blood-clot imbedded in it, and all its other characters, satisfactorily proved that it had been a thin clot of blood,—an example of such as are effused in apoplexy of the cerebral membranes, and are fully described by Mr. Prescott Hewett.*

FIG. 13.



Numerous small vessels could be seen passing from the dura mater into this clot-membrane; and with the microscope, while they were still full of blood, I made the sketch which is here engraved (Fig. 13, A.) The arrangement of the blood-

* Med.-Chir. Trans. vol. xxviii.

vessels bears a close resemblance, but, perhaps, more in its irregularity than in any positive characters or plan, to that which exists in false membrane formed of organized lymph : but the vessels were, I think, generally larger.

Such were the blood-vessels of this organized clot. Its minute structure, as represented above (B.), showed characters which are of peculiar interest, because of their resemblance to those observed in the material that is commonly formed in the repair of subcutaneous injuries. In the substance of what else appeared like a filamentous clot of fibrine, sprinkled over with minute molecules, the addition of acetic acid brought into view corpuscles like nuclei, or cytoblasts, very elongated, attenuated, and, in some instances, like short strips of flat fibre. Of course, such corpuscles are not to be found in any ordinary clot of fibrine ; they exactly resemble such as may be found in certain examples of rudimentary cellular tissue, and, among these, in the material for the repair of subcutaneous injuries. In short, the minute structure of this clot now organized was an example of what I shall have often to refer to under the name of " nucleated blastema."*

With such evidence as this of the organization of a thin layer of blood-clot, and of the development of its fibrine being apparently identical with that of the material commonly formed for the repair of subcutaneous injuries, I was surprised to find that extravasated blood can, commonly, have no share at all in the reparative process.

One of the best proofs of this is, that scarcely the smallest portion of blood is effused in the cases in which the largest

* The description here given has been fully confirmed by the examination of a similar membranous clot, the vessels of which were beautifully injected by Mr. Gray (Pathol. Trans.) ; and more recently by that of one injected by Mr. Coote.

quantity of reparative material is produced in the shortest time, and in which the healing process is most perfectly accomplished. In twenty cases in which I divided the Achilles-tendon in rabbits, I only once found, in the subsequent examinations, a clot of extravasated blood in the track of the wound. In this case, I believe, the posterior tibial artery was wounded : for in all others, and in similar divisions of muscles, unless a large arterial trunk were cut, the only effusion of blood was in little blotches, not in separate clots, but effused or infiltrated in the cellular tissue near the wound. In some cases there was blood-stained infiltration of the inflammatory products, but in none were there such clots as could be organized into bonds of union. In short, parts thus divided scarcely bleed : what blood does flow escapes easily through the outer wound, as the surrounding tissues collapse into the space left by the retracting parts ; or, what remains is infiltrated into the tissues, and forms no separate clot.

It is the same with fractures. In a large proportion of these, one finds no clots lying between the fragments where they are to be united, and only very small spottings of blood, like ecchymoses, in or beneath the periosteum. The abundant extravasations that commonly exist in the subcutaneous tissue are generally confined to it : they are not continued down to the periosteum or bone.

In all these cases, then, we have sufficient proof that extravasated blood is not necessary for union by the first intention, or for any other mode of repair, in the simple fact that where the repair is best, and the material for it most ample, no blood is so extravasated as to form a clot that could be organized.

But, though this may be the usual case, the question still remains—When blood is effused and coagulated between wounded surfaces, how are the clots disposed of? For,

often, though not generally, such clots are found in wounds, or between the ends of a broken bone, or a divided tendon when an artery by its side is cut; and in most operation-wounds, one sees blood left on them, or flowing on their surfaces, after they are done-up. How, then, is this blood disposed of?

If effused in large quantity, so as to form a voluminous clot, and especially if so effused in a wound which is not perfectly excluded from the air, or if effused in even a subcutaneous injury in a person whose health is not good, it is most likely to excite inflammation; and the swelling of the wounded parts, or their commencing suppuration, will push it out of the wound. Thus we often see blood ejected.

But, in more favourable circumstances, the blood may be absorbed; and this may happen whether it have formed separate clots, or, more readily, when it is infiltrated in the tissues. What I have seen, however, in the experiments to which I have already referred, leads me to dissent from the account commonly given of the absorption of blood thus effused. The expressions generally used imply that the first thing towards the repair of such a wound is the absorption of the extravasated blood; and that then, in its place, the lymph or reparative material is produced. But this can hardly be the case; for the absorption of blood is a very slow process, and commonly requires as much time as would suffice for the complete healing of a wound, or even of a fracture. Not to mention the very slow absorption of the extravasations of blood in apoplexy, or in serous sacs, I have found the blood effused in the subcutaneous tissue and the muscles, after a simple fracture, scarcely changed at the end of five weeks; that in a tied artery was as little changed after seven weeks: and even in common leech-bites we may sometimes find the blood-corpuscles, in little ecchymoses,

unchanged a month after their extravasation : yet in much less time than this it is commonly implied that all the blood extravasated in an injury is cleared quite away, that lymph may occupy its place. My impression is, that this opinion is founded on imperfect observations. Blood is supposed to be effused in all subcutaneous injuries ; and where it is not found, it is supposed to have been absorbed ; the truth rather being, that, where no blood appears, none ever was.

The true method of the absorption of blood left in a wound seems to be, that it is enclosed within the reparative material, and absorbed by the vessels of that material as its organization proceeds. The best instance in support of this that I have seen was in the case of a rabbit's Achilles tendon, divided subcutaneously six days before death. The reparative process had proceeded favourably, and as strong a band of union as is usual at that period was formed of the new reparative material deposited between the retracted ends. On slitting open this band, I found within it a clot of blood, such as must have come from a large vessel ; and this clot was completely enclosed within the new material ; not closely adherent to it, nor changed as if towards organization ; but rather, decolorized, mottled, and so altered as clots are in apoplexy before absorption.

I believe that this case only showed in a very marked manner what usually happens with blood thus effused and not ejected : for it is quite common, after the division of tendons, to find new reparative material, if not containing distinct clots, yet blotched with the blood that was infiltrated in the tissue in which the reparative material is deposited : and even when the repair of a fracture was nearly perfect, I have still found traces of blood-corpuscles enclosed in the reparative material, and degenerating, as if in preparation for absorption.

Ejection and absorption are, doubtless, the usual means

by which blood effused in injuries is disposed of; yet I feel nearly sure it may in some instances become organized, and form part of the reparative material. The cases of manifest organization of blood already referred to leave no doubt of the possibility of this happening: its occurrence can no longer be set aside as a thing quite improbable. The only question is, whether blood effused in injuries has been seen organized. Now I think no one familiar with Hunter's works will lightly esteem any statement of his as to a matter of observation. He may have been sometimes deceived in thinking that he saw blood becoming organized in subcutaneous injuries (for subcutaneous granulations are sometimes very like partially decolorized clots); yet I believe he was often right: for sometimes one finds clots of blood about the fractured ends of bones which have every appearance of being in process of organization. They do not look mottled, or rusty, or brownish, as extravasated blood does when it is degenerating, preparatory to its absorption; but they are uniformly decolorized to a pinkish-yellow hue. They have more appearance of filamentous structure than recent clots have; and they are not grumous or friable, like old and degenerating ones, but have a peculiar toughness, compactness, and elasticity, like firm gelatine. When clots are found in this condition, I believe it is a sign that they were organizing; for this is the condition into which, commonly, the clot in a tied artery passes in its way to be fully organized; and (which is very characteristic) you may find clots in the track of wounded parts thus changing, as if towards organization, while those about them, and out of the way of the reparative process, are degenerating.

On the whole, then, I believe we may thus generally conclude concerning the part that blood, when it is extravasated, takes in the repair of injuries:—

1. It is neither necessary nor advantageous to any mode of healing.

2. A large clot, at all exposed to the air, irritates and is ejected.

3. In more favourable conditions the effused blood becomes enclosed in the accumulating reparative material ; and while this is organizing, the blood is absorbed ; and,

Lastly, it is probable that the blood may be organized and form part of the reparative material ; but even in this case it probably retards the healing of the injury.

I proceed now to the consideration of the new material which is produced for the repair of injuries that are not healed by the immediate union. It is that to which the general name of lymph, or coagulable lymph, is given.

Our notions concerning the properties of this substance, when once formed for the repair of injuries, are derived almost entirely from examinations of the lymph formed in acute inflammations, with which it is supposed to be identical. The identity is far from being proved, but their similarity is in many particulars evident, and especially in that both manifest, by their spontaneous coagulation, that they contain fibrine. The coagulum which is spontaneously formed in reparative material is, in microscopic characters, like that of fibrine : chemically, too, they appear alike : and the organization of the fibrine of the blood in the complete clot, as well as all the other circumstances which lead to the opinion that fibrine is the principal material for organization into tissues, justifies the belief that the lymph exuded for the purposes of repair has fibrine for its principal constituent. However, when we speak of fibrine as the chief reparative material, we must not have in mind the pure organic compound that minute chemistry

might obtain, but rather that which exists in the natural, and seemingly rough, state,—as fibrine, with some fatty matter, and some incidental saline constituents ; for all these are found in all the specimens of coagulable lymph that have been examined ; and doubtless they are essential, as the so-called “ incidental ” principles always are, to the due construction of the substance to be organized.

Regarding its vital properties, the essential character of the coagulable lymph is its tendency to develop itself ; a tendency which it has of its own properties. It thus displays itself as a plasma or blastema ; a fluid to be classed with those others that manifest the capacity to assume organic structure ; such as the lymph and chyle that develop themselves to blood, and the semen, which, at first fluid, gradually develops itself into more and more complex structures.

The natural tendency of coagulable lymph is to develop itself into the fibrous, or the common fibro-cellular or connective, tissue—the lowest form of vascular tissue, and the structure which, in nearly all cases in man, constitutes the bond by which disunited parts are again joined. This is commonly formed, whatever be the tissue upon which the lymph is placed, whether containing cellular tissue in its natural structure or not. This, therefore, we may regard as the common or general tendency of lymph ; but in certain cases the development of lymph passes beyond this form, or deviates from it into another direction, in adaptation to the special necessity of the part to be repaired. Thus, for the repair of bone, the lymph may proceed a certain distance towards the development of fibrous tissue, as if for a common healing ; but this fibrous tissue may next ossify ; or, not forming fibrous tissue at all, the lymph may proceed at once to the formation of a nearly perfect carti-

lage, and this may ossify. In general, moreover, the character of the connective tissue that is formed in repair is adapted to that of the parts that it unites. The bond for the union of a tendon is much tougher than a common scar in the skin; the scar in skin is tougher and less pliant than that in mucous membrane, and so on.

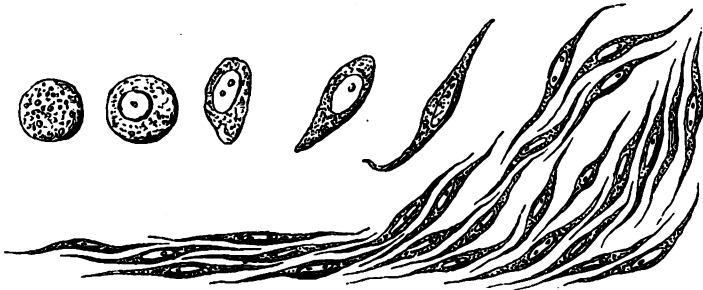
But, passing by, for the present, the instances of special development of the reparative material, in adaptation to special purposes or injuries, let me speak of its development into fibrous, fibro-cellular, or connective tissue. I have said that, in its first production, the reparative material is like the lymph of inflamed serous membranes; at least, no characteristic difference is yet known between these, which we might call respectively, inflammatory and reparative lymph. Neither are there yet any observations to show a difference in the primary characters of the materials effused for the repair of injuries of different parts, or in different circumstances; and yet such a difference, in even the original properties of the reparative lymph, is indicated by the fact, that, in different circumstances, it may proceed to the same end—the formation of fibrous tissue—by two different ways of development. The lymph, or new material, which is produced for the repair of open wounds, generally develops itself into fibro-cellular tissue through nucleated cells; that formed for the healing of subcutaneous wounds as generally develops itself into the same tissue through the medium of nucleated blastema.

Now, both these are repetitions of natural modes of development of the same forms of tissue. And it must not appear an objection that there should be two modes of development to the same perfect structure; for this is usual, and has been observed in nearly all the tissues. In the development of the blood-corpuscles, a first set are formed from

part of the embryo-cells that form the germinal area, or the whole body of the embryo; and a second set are formed, I believe, exclusively from the corpuscles of lymph and chyle. So it is with the cartilage, the muscular, and other tissues that are formed in the earliest periods of embryo-life. At first they are developed from some of the embryo-cells; yet in later life no such cells are seen among them, but others appropriate to them, and of different form. So also in the bones, which at first are developed through cartilage, but in their subsequent growth are increased by ossification of fibrous tissue; and in the repair of which we shall find even more numerous modifications of these different developments.

The development of the fibro-cellular or connective substance through nucleated cells may be observed in the material of granulations, or in that of inflammatory adhesions (whether in a serous sac or in a wound healing by

FIG. 14.*



primary adhesion), in inflammatory indurations, and in the naturally developed fibro-cellular tissue of many parts.

* Development of granulation cells; the elongated cells in the group below are sketched as less magnified than those above.

The process is, with slight and apparently not essential modifications, the same in all; and is, I believe, almost exactly described by Schwann.

The cells first formed in granulations are spherical, palely or darkly nebulous, from about 1-1800th to 1-2500th of an inch in diameter. They contain a few shining, dark-bordered granules, and lie imbedded in a variable quantity of clear pellucid substance, by which they are held together, and which it is hard to see, unless acetic acid be added. When water is added, it penetrates the cells, and as they swell-up their walls appear more distinct, and their contents are diffused. Some cells thus become much larger and clearer, and show in their interior numerous vibrating molecules: others display fewer molecules, but a distinct, round, dark-bordered nucleus, which appears attached to the inside of the cell-wall. Such a nucleus is rarely seen in granulation-cells, unless they are distended with water: acetic acid, acting more quickly than water, brings the nucleus more evidently and constantly into view, and often makes it appear divided into two or three portions.*

In the development of cellular or connective tissue from these cells, whether in the natural structures or in those that are formed in disease or after injury, the first apparent change is in the nucleus. It becomes more distinct; then oval (even before the cell does), and at the same time clearer,

* The granulation-cells are very like the white or lymph-corpuses of the blood: but the likeness implies nothing more than the general fact that many structures which, in their perfect state, are widely different in form as well as in office, have, as to form, the same rudimental elements. The fact, of which there are many other instances, seems the more remarkable, if we contrast it with that already mentioned,—that the same perfect structure may have more than one original or rudimental form, and more than one method of development.

brighter, like a vesicle tensely filled with pellucid substance. One or two nucleoli now appear distinctly in it, and soon it attenuates itself; but this it does later, or in a less degree, than the cell: for a common appearance is that of elongated cells bellied-out at the middle by the nucleus.

While these changes are ensuing in the nucleus, each cell also is developing its structure; first becoming minutely, yet more distinctly, granular and dotted; then having its cell-wall thinned, or even losing it. It elongates at one or both ends, and thus are produced a variety of lanceolate, caudate, or spindle-shaped cells, which gradually elongate and attenuate themselves towards the filamentous form. As they thus change, they also group themselves; so that, commonly, one may find the swollen part of each, at which the nucleus lies, engaged between the thinner parts of the two or more adjacent to it. Thus, the filaments into which the cells are developed are clustered or fasciculated: each cell forming, I think, usually, only one filament, and long filaments being sometimes formed by the attachment of the ends of two or more, each developed from a single cell.

The final disposal of the nuclei of these cells is not clear. In the development of the cellular tissue formed in inflammation or granulating wounds, they seem to waste and be absorbed. Certainly such nucleus-fibres as Henle supposed to be formed from them are not found in recent scars, though common in those of old standing.

In some granulations, but, I think, only in such as are formed on bones, one may often find large compound cells, or masses or laminæ of blastema, of oval form, and as much as 1-250th of an inch in diameter, containing eight, ten, or more nuclei. They are like certain natural constituents of

the medulla of bone (as described by Kölliker* and Robin†); and like the bodies which are found constituting the chief part of fibro-plastic tumours. Sometimes, also, even in the deeper parts of granulations, cells are found expanded, flattened, scale-like, and nucleated, as if approximating to the formation of epidermal cells.

Such, briefly, is the process for the development of fibro-cellular tissue through nucleated cells as observed in granulations. Some modifications of it may be noticed in certain cases, especially in regard to the proportion that the cells bear to the substance in which they lie. In some forms of granulations, as in some natural parts of the embryo, this substance is abundant; and I presume that by its development or fibrillation it takes part in the formation of filaments. But none of the modifications affect the essential characters of the process.

The development of fibro-cellular or fibrous tissue through nucleated blastema is, as I have already said, best observed, among the processes of repair, in the organization of the material by which, in most cases, the bonds of connection after subcutaneous wounds are formed. It is the same process which Henle‡ regards as the only mode of development of the fibro-cellular and fibrous tissues.

Of the union of divided tendons I hope to speak more fully in a future lecture. For the present purpose, and in illustration of the development of fibro-cellular or fibrous tissue from nucleated blastema, it may be enough to state that, when the first exudation of the products of the inflammation, excited by

* Mikrosk. Anatomie, Fig. 113, 121.

† Bull. de la Société de Biologie, 1849, p. 150.

‡ Allgemeine Anatomie. A similar process is described by Reichert, Zwicky, and Gerlach.

the violence of the wound, is completed, a quantity of finely molecular or dimly-shaded substance, like homogeneous or dotted fibrine, begins to appear in the space in which the bond of union is to be formed. This substance is infiltrated in the tissue that collapses into the space between the retracted ends of the tendon. At first there is no appearance of nuclei or cytoblasts in it: it seems to be merely a blastema of fibrin; but, as it acquires firmness and distinctness, the nuclei appear in it. These seem to form out of collecting clusters of granules; they presently appear as oval bodies, with dark hard outlines, soon becoming elongated; they have clear contents, without nucleoli: they are irregularly scattered, but so firmly imbedded in the blastema that, in general, they cannot be dislodged. They may be seen in very fine fragments without reagents; but, commonly, the application of acetic acid is necessary to make them distinct, by making the intermediate substance transparent, while the nuclei themselves appear to acquire darker edges and shrivel a little. The nuclei undergo comparatively little change, while the blastema in which they are imbedded is acquiring, more and more distinctly, the filamentous appearance, and then the filamentous structure. Only, they appear to elongate, and to attenuate themselves, and to grow more irregular in their outlines, as if by shrivelling, or by slight branching.

The blastema may become at length perfect fibro-cellular or fibrous tissue; a tissue not to be distinguished from that found in normal conditions. I have not been able to find, as Henle describes, that the nuclei are developed into fibres. In the process of repair by tissue thus developed, as well as by that which is formed through cells, my impression is that the nuclei finally shrivel; gradually contracting into:

FIG. 15.



little crooked or branched lines, and at length disappearing : for, as I have already said, well-formed nucleus-fibres, or such elastic yellow fibres as might be developed from them, do not generally occur in cicatrices of recent formation, or in the large bonds of union by which divided tendons are healed.

I have been thus minute in the account of these two modes of development of fibro-cellular tissue, prevailing alike in the natural structures and in the materials of repair, because the knowledge of them may enable us to settle some questions respecting all the modes of healing, and because it seems to point out the essential anatomical difference in the healing of open and of subcutaneous wounds, with disconnection of divided parts.

The general truth appears to be (as already stated) that the material of repair for subcutaneous wounds of soft parts is developed through the formation of nucleated blastema ; while that for repair by primary adhesion, and by granulation, is developed through nucleated cells. Now, since both these methods of development are, as I have already said, imitations of natural methods, we might suppose that they are, therefore, both alike natural or healthy processes ; alike sure to pass to their purposed end, safe from disease or degeneration. But, if we consider also the morbid conditions in which these two methods of development occur, we may find that the development through cells is characteristic of a less perfect process of healing than that accomplished with the nucleated blastema that appears to originate in a fibrinous exudation. For, in describing the products of inflammation, I shall have to show, that in general, the inflammatory exudations which occur in plethoric sthenic conditions of the system, or in local disease in persons otherwise sound, have the aspect of fibrinous substance, like the mate-

rials which are produced in subcutaneous injuries, and are developed through nucleated blastema; while, on the other hand, the inflammatory exudations in debilitated persons, and in asthenic blood-diseases, assume a corpuscular structure, like that of granulations upon open wounds.

Let me, however, in conclusion, state that, although I have described the two modes of development of fibro-cellular or fibrous tissue for the healing of wounds as if they were always as separate as they are distinct, yet they may co-exist, and probably often do so. In the repair of many wounds, the two materials, namely, that which is to be developed through nucleated cells, and that whose progress is to be through nucleated blastema, may be mixed. Thus, in subcutaneous wounds and injuries, the first consequence of the mechanical violence is the exudation of a common inflammatory product, which makes the cellular tissue œdematous, and usually organizes itself into nucleated cells. Thus you find the space between the retracted parts of divided tendons for about two days. But, then, the more proper and purer material of repair is produced; and this, increasing in an inverse proportion to the degree of inflammation, soon overwhelms the former product of inflammation, and is developed into the nucleated blastema. Still, for many days, traces of the inflammatory product may be discerned mingled with the blastema, confusing its appearance, but, I believe, finally organizing with it into the bond of union. So, in divided muscles, and in simple fractures, the inflammatory exudation, produced in consequence of the first violence, appears to mingle and develop itself with the more proper material of repair; but they bear an inverse proportion to one another, and the more manifest the signs of the inflammation, the less is the quantity of the proper reparative material, and the slower, in the end, the process of repair.

On the other hand, I think that in the ordinary healing of open wounds, which are soon brought together by sutures, or other appropriate means, there may be less than the commonly observed formation of nucleated cells, and some of the reparative material may be developed through the nucleated blastema. Or, when the different materials are not mingled at the same spot, yet, in a single wound, different parts may be healed by the organization of one or other material, according to the degree of inflammation that is in each part present.

LECTURE IX.

THE PROCESSES OF REPAIR OF WOUNDS.

I PROCEED now to the description of the several modes of healing of wounds, and shall at present speak of only such wounds as are externally open. Among the modes which I enumerated, the first was that which, as I stated in the preceding lecture, is effected by immediate union. It corresponds with what Mr. Hunter called union by the first intention; but, since that term has been applied more recently to another mode of healing, I have adopted the term "immediate union" from Dr. Macartney, who, so far as I know, was the first to observe clearly that the healing of wounds may be effected "without any intervening substance, such as blood or lymph."* He says—"The circumstances under which immediate union is effected, are the cases of incised wounds that admit of being, with safety and propriety, closely and immediately bound up. The blood, if any be shed on the surfaces of the wound, is thus pressed out, and the divided blood-vessels and nerves are brought into perfect contact, and union may take place in a few hours; and as no intermediate substance exists in a wound so healed, no mark or cicatrix is left behind.

"We have familiar examples of this mode of healing in slight cuts received on the fingers, which, after being bound

* Treatise on Inflammation, p. 49.

up, if no inflammation be induced, perfectly heal without the individual having any unpleasant sensation in the part after the moment of the infliction of the wound. A case has been lately communicated to me, of a considerable cut of the hand having been cured by this mode of direct union, without any sensation of pain, in the short space of four or five hours."

It is singular that Dr. Macartney should speak of the process of immediate union occurring in so few and very trivial instances as these; for it seems certain that many even very large wounds are usually, in favourable circumstances, thus healed. The characteristics of this mode are, that the divided parts, being placed in exact contact, simply conjoin or re-unite: no blood or new material is placed between them for a connecting bond, and no sign or product of inflammation is present. All these characters meet in such cases as the favourable union of flaps of skin, which have been reflected from the subjacent parts, and are then replaced or transferred to some other adjacent wounded surface.

The instances in which I have best observed it have been after wounds reflecting portions of the scalp, and after operations for the removal of the mammary gland. In these operations, as you know, the usual proceeding is to remove some of the skin, including the nipple, and to uncover the rest of the surface of the gland by reflecting from it an upper and lower flap of skin. Then, the gland being removed, these flaps, which are often of considerable extent, are laid down upon the parts on which the base of the gland rested, chiefly upon the fascia over the great pectoral muscle.

One of the first specimens I examined well illustrated the healing that may now ensue. It was taken from a woman thirty-three years old, whose breast and several axillary glands were removed for cancer. Her general health seemed

good, and all went on well after the operation. The flaps, which were of course very large, had been carefully laid down, strapped with isinglass plaster, and well tended. They appeared to unite in the ordinary way, and there remained only a narrow space between their retracted edges; in which space granulations arose from the pectoral muscle. Three weeks after the operation these were making good progress towards cicatrization; but erysipelas and phlebitis ensued, and the patient died in four or five days.

I cut-off the edges of the wound with the subjacent parts, expecting to find the evidences of union by organized lymph, or, possibly, blood. But neither existed; and the state of parts cannot be better described than by saying that scarcely the least indication remained of either the place where the flap of skin was laid on the fascia, or the means by which they were united. It was not possible to distinguish the relation which these parts held to each other from that which naturally exists between subcutaneous fat and the fascia beneath it. There was no unnatural adhesion; but, as the specimen, which is in the Museum of St. Bartholomew's, will still show, the subcutaneous fat which did lie over the mammary gland was now connected with the fascia over the pectoral muscle, just as (for example) the corresponding fat below the clavicle is naturally connected to the portion of the same fascia that lies there. The parts were altered in their relations, but not in their structure. I could find small points of induration where, I suspect, ligatures had been tied, or where, possibly, some slight inflammation had been otherwise excited; and one small abscess existed under the lower flap. But with most careful microscopic examination, I could discover no lymph- or exudation-corpuscles, and only small quantities of what looked like the débris of such oil-particles or corpuscles of blood as might have been between the cut surfaces when the

flaps were laid down. In short, we cannot otherwise or more minutely describe this healing than by the term "immediate union:" it is immediate, at once in respect of the absence of any intermediate substance placed between the wounded surfaces, and in respect of the speed with which it is accomplished.

Opportunities of examining wounds thus healed being rare, I made three experiments on rabbits (with my friend Mr. Savory), and found the description I have just given quite confirmed. A portion of skin, which my extended fingers would just cover, was raised from the back of a rabbit, replaced, and fastened down with a few sutures. Three days afterwards the rabbit was killed. The edges of the wound were slightly retracted, and the space between them was covered with scab: for about half an inch under the edge of the replaced flap of skin, the tissue was inflamed and infiltrated with exudation-matter; but beyond this no trace of the injury or of its healing could be seen. The parts appeared as they had appeared before the operation. Even the microscope could detect only a slight infiltration of inflammatory matter, which one might certainly ascribe to the wound being open at its edges, and to some hairs having by accident been enclosed under the flap when it was replaced.

Of course, it is only from such examinations as these after death, that we can speak certainly of the absence of inflammation and of all intermediate uniting substances; yet confirmatory evidence may be obtained from the examination of any such wound during life,—I mean in any such case as that of a flap of skin raised up, then laid down on the subjacent wounded surface, and there uniting favourably; or in any case of that kind of plastic operation in which a flap is raised, and then made to slide to some further position. In such cases, with favourable progress, no sign

of inflammation is observed ; though, if the skin were in even a small degree inflamed, it could scarcely fail to be manifested by the ordinary appearances of redness and heat. If the flap be pressed, no fluid oozes beneath its edges, (I speak, of course, of only such cases as are making favourable progress) ; and after one or two days, according to the extent of the wound, the flap will move on the subjacent parts, not with the looseness of a part separate from them, nor with the stiffness of one adherent through inflammation, but with the easy and pliant sliding which is peculiar to the natural connection of the skin with the subjacent fascia.

Such is the nature of "immediate union ;" the best imaginable process of healing. Two conditions appear essential to it : first, exactness of the coaptation of the wounded surfaces ; and secondly, the absence of all inflammatory process.

To obtain the former, the simple replacement of the raised pieces of skin may sometimes be sufficient. But there is a class of cases to which this mode of healing is peculiarly applicable, and in which more than this may be required : I refer to the removal of large subcutaneous tumours,—fatty tumours and the like,—where, after the operation, large cavities are left, and commonly left to granulate. In these cases I believe that modern surgery does not often enough employ the older method of carefully and softly padding the parts, and of so bandaging them that the exposed surfaces may be held in contact for the one, two, or three days necessary for immediate union. Many surgeons, I know, commonly employ these means, but by many they are avoided, through fear of exciting inflammation by over-heating the parts, or hindering the discharge of secreted fluids. Doubtless, no single rule of management would be safe ; but I think, with regard to this fear of exciting inflammation, it need not be entertained, if the

means I have alluded to be employed only during the first two or three days after the infliction of the wound. For one may generally observe that, for at least two or three days after such an injury as an amputation, the raising of a flap of skin in a removal of the breast, or the like, scarcely any reparative process appears in the parts that are kept from contact; no granulations are formed, no pus secreted, only a little serous-looking fluid oozes from them. Now, during this calm, which would certainly not be disturbed by the parts being softly padded and kept in perfect rest, the immediate union may be accomplished. If, through any untoward circumstance, it be not in this period completed, its occurrence is, I believe, impossible, and then the means more appropriate for other methods of healing may be employed.

The attainment of the other necessary condition, the absence of inflammation, is quite consistent with these means for insuring perfect and continued contact of the wounded surfaces. How the condition is to be fulfilled I need not say: the means are some of those that are commonly laid down for preventing inflammation from being, as it is said, more than is necessary for the union by the first intention; and the best of them are temperance, rest, and uniform temperature. The necessity of observing them will appear the greater, if it is remembered that what is wanted for immediate union is, not a certain undefined slight degree of inflammation, but the complete absence of inflammation; for the probability of the occurrence of immediate union may be reckoned as being in an inverse ratio to the probability of inflammation occurring in the time necessary for its accomplishment.

The second mode of repair that I enumerated is that by *primary adhesion*.

This is the process which Mr. Hunter named union by

adhesion, or union by the adhesive inflammation. My reasons for preferring the term "primary adhesion" will presently appear. He says: "Where the former bond of union," [*i. e.*, the union by blood or by the first intention], "is lost in a part, to produce a new one a second operation takes place, namely, inflammation."* Observe how carefully Mr. Hunter distinguishes the case in which inflammation ensues, from that in which none is necessary: and presently after—"If the divided parts are allowed to remain till the mouths of the divided vessels are entirely shut, inflammation will inevitably follow, and will furnish the same materials for union which are contained in extravasated blood, by throwing out the coagulated lymph; so that union may still take place, though some time later after the division of the parts. This inflammation I have called the adhesive." On this sentence, Mr. Palmer, expressing the opinion entertained by all the pathologists of ten or twelve years ago, says—"It is now generally considered that union by the first intention and adhesive inflammation are essentially the same processes, modified by the degree of inflammation. Union by the first intention is uniformly attended with some degree of pain and swelling, together with increased heat and vascularity, which, taken conjointly, constitute the definition of inflammation." And again: "According to the modern views, the modes of union above detailed" [*i. e.*, the modes of union included by Mr. Hunter under the union by the first intention], "are always accompanied by adhesive inflammation.....The parts are united, not by the extravasated blood becoming vascular, but by the effusion and organization of coagulable lymph."

After what I have said respecting the process of immediate union, it may appear that Mr. Hunter was more

* Works, vol. iii. p 253.

nearly right than his successors. It would be an instructive piece of the history of surgery, to show, exactly, how his truth, being mixed with error, came, therefore, to be thrown away, and to make room for an error which had less truth mixed with it. The stages of transition in opinions seem to have been, that, first, sufficient reason was found for disbelieving Hunter's statement, that blood forms the bond of union by the first intention; then, as it was assumed that there must always be some intermediate bond, this, it seemed, could be none but coagulable lymph. Now, coagulable lymph being known only as the product of inflammation, it followed that inflammation must be necessary for the healing of every wound; and then there ceased to be any distinction between the union by the first intention and the union by adhesion; both alike seemed to be the result of lymph, the product of inflammation, being exuded between the wounded surfaces, and united to them both.

Typical examples of union by primary adhesion may be watched in the cut edges of skin that are brought near together. When the cut surfaces are not in exact contact, the wound is exposed, and lymph is formed, and fills up the space; or, when they are in contact, the sutures, or other means employed to keep them so, excite inflammation enough for the production of some lymph between them. The lymph is simply laid on the cut surfaces; and scarcely any is infiltrated in the tissues. Organizing itself, and becoming vascular, it connects the two edges or surfaces, and, finally, forms between them a thin layer of cellular tissue, on the surface of which, if it be exposed, a very delicate layer of cuticle is developed. The smooth shining surface of this cuticle gives the peculiar character of the scar, and one that scarcely changes, except in the

alteration of apparent colour when the new material becomes less vascular.

The lymph effused in the healing by primary adhesion always, so far as I know, develops itself through nucleated cells, and, doubtless, the whole process is very similar to that of the adhesion of inflamed serous membranes.

It may be very quickly accomplished. A boy died eighty hours after receiving a lacerated wound of the abdomen; and, for forty-eight hours of these eighty, he was so manifestly dying, that I think no reparative process could have been going on. A portion of the edges of the wound was united with lymph, which presented well-marked cells, like those of granulations, and contained looped blood-vessels full of blood.

But it may be accomplished more quickly than in this case. In a rabbit that I operated on as for hare-lip, I found, after forty-eight hours, the edges of the wounds partially, but firmly, united by lymph, many of the cells of which were already elongated, in such development as I have already described. Or, even more quickly than in this instance:—if a small abscess be opened, and the edges of the opening are not gaping or inverted, they may be found united, except at the middle, within twenty-four hours. I have seen them so united, with a distinct layer of soft, pinkish, new substance, in a wound made seventeen hours previously.

There are no cases in which the process of primary adhesion can be better observed than after operations for hare-lip. The inner portions of the wounds made in them may be healed by the immediate union, when the surfaces have been in exact coaptation; but the edges of the skin and mucous membrane seem always united by the adhesive inflammation, for a scar is always visible—a scar

formed by the lymph organized into cellular tissue and epithelium, and one which, as well as any, shows how little of assimilative force can be exercised by adjacent tissues; for, narrow as it may be, it does not become quite like the adjacent skin, nor, like it, bear perfect epidermis and hair.

The history of union by primary adhesion cannot be conveniently completed till an account has been given of the healing by granulation and by secondary adhesion. Of these I will next speak: now I will only say of this union by primary adhesion, that it is less desirable than the immediate union, because 1st, it is, probably, not generally so speedy; 2dly, it is not so close, and a scar is always formed by the organization of the new matter; and 3dly, the formation of lymph- or exudation-cells is a process so indefinitely separated from that of the formation of pus-cells, that union by primary adhesion is much more likely to pass into suppuration than any process is in which no lymph is formed.

In describing the modes of healing by *granulation* and by *secondary adhesion*, I shall venture again to take my account from certain typical examples: such as cases in which, after amputation of a limb, the surfaces of the wound are not united by either of the means already described, but, as the expression is, are "left to granulate;" or such cases as the removal of a breast, and subsequent suppuration of the flaps and the exposed fascia; or such as wounds into inflamed parts, when the edges gape wide asunder, and the spaces left between them are filled-up with granulations. These may serve as examples of a process which, although in all cases it may preserve certain general features of similarity, is yet in detail almost infinitely

diversified, and often so inexplicably, that any more than a general account of it might fill volumes.*

Granulations will generally arise on all wounded surfaces that are left open to the air and are not allowed to dry. They will do so whether this exposure be continued from the first infliction of the wound, or commence after the edges, which have been brought together, have been again forced asunder by the swelling of the deeper-seated parts, or by hæmorrhage, or secretion of fluid, between them. Exposure of a wound to the air is not prevented by any ordinary dressings : the air that is enclosed beneath them, or that can penetrate them, appears to be quite enough to determine all the difference of the events that follow open and subcutaneous injuries.

The simplest case for illustration is that of an open gaping incised wound, which, from the time of its infliction, is only covered, as in ordinary practice, with water-dressing, or some soft and moist substance. Blood gradually ceasing to flow from the surface of such a wound, one may see still some blood-tinged serous-looking fluid oozing from it. Slowly, as this becomes paler, some of it collects, like a whitish film or glazing, on the surface ; and this, if it be examined with the microscope, will be found to contain an abundance of the white corpuscles of the blood, imbedded apparently in a fibrinous film. The collection of these corpuscles on the surface of the wound, especially on wounded muscles and fasciæ, appears to depend only on their peculiar adhesiveness. One sees them adhering much more firmly than ever the red corpuscles do to the walls of the minute blood-vessels,

* Some of the most important modifications of the process occur in gun-shot wounds. These are admirably described by Mr. Guthrie in the *Lancet*, Feb. 14, 1852.

and to the glass on which they are examined ; and so on cut surfaces, while the other constituents of the blood flow away, the white corpuscles, and, probably, also, some of the fibrine quickly coagulating, adhere.*

I am not aware of any facts that would prove what share the white corpuscles thus collected may take in the healing of a wound. They do not hinder it ; for it is by many believed to be favourable to union by primary adhesion, to leave cut surfaces exposed, till they appear glazed-over with the whitish film, and then to put them into contact. It is probable the corpuscles are organized when the surfaces that they cover are brought together ; but I know of no facts bearing on the point, and it is one which I think experiments on animals could hardly be made to illustrate.

If a wound be left open, the glazing remains on such parts as it may have formed on, especially on the exposed muscles. No evident change ensues in it, except that it appears to increase slowly, and makes the surface of the wound look as if covered with a thin greyish or yellowish-white layer of buffy coat. This increase of glazing is the prelude of the formation of granulations ; but while it is going-on, and, often, for some days later, there is, in and about the wound, an appearance of complete inaction ; a calm, in which scarcely anything appears except a slight oozing of serous fluid from the wound. Such a calm con-

* Reinhardt, by whom, I think, the fact was first clearly noticed (Traube's Beitrage, H. ii. p. 188), supposes the white corpuscles may exude separately from the vessels. Perhaps the truth is, that their peculiar adhesiveness makes them flow less readily from the bloodvessels, when the bleeding is about to stop ; so that at last, when the vessels finally close and empty themselves, a large proportion of these corpuscles may issue from them and adhere to the cut surface over which they slowly roll.

tinues from one day to eight, ten, or more, according to the nature and extent of the wounded part, and the general condition of the body. In a cut or sawn hard bone, about ten days will generally elapse before any change is manifest ; in cancellous bone the change ensues a few days more speedily : on the under surface of a large flap of skin, with subcutaneous fat, three days may thus pass without change ; on the cut or excoriated surface of the more vascular part of the skin, two days or three.

These periods of repose after severe injury are of equal interest in physiology and in surgery ; but in the former it is chiefly the interest of mystery. Observations on injuries of the frog's web* make it probable that the blood is stagnant in the vessels for some little distance from the wound during several days after the injury : but why it is so, and what are the changes ensuing in and about it, preparatory to its again moving on, we cannot quite tell. The interest to the surgeon watching this period of repose is more practical. The calm may be the brooding-time for either good or evil ; whilst it lasts, the mode of union of the wound will, in many cases, be determined : the healing may be perfected, or a slow uncertain process of repair may be but just begun ; and the mutual influence, which the injury and the patient's constitution are to exercise on one another, appears to be manifested very often at or near the end of this period. Moreover, in open wounds, the time at which, on each tissue, granulations are produced, is determined by this calm ; for they begin to be distinctly formed at its end. Thus, on a stump, after a circular amputation, one may find

* See especially those detailed by Mr. Travers in his *Essay on Inflammation and the Healing Process* : and those by Mr. Wharton Jones, *On the State of the Blood and Blood-vessels in Inflammation*.

the margin of the skin and the surface of the muscles well covered with granulations, while the surface of the fat reflected with the skin is barren of them, and the sawn walls of the bone are dry and bare. But from the sawn end of the medullary tube there may already protrude a florid, mushroom-shaped mass of granulations, overhanging the adjacent walls: as if parts in which nutrition is habitually carried on under restraint, within hard and rigid boundary-walls, were peculiarly apt to produce abundant organizable material as soon as they are released.* Generally, also, the granulations springing from these different tissues observe the same order in their rate of development as in their first appearance. Those that first take the lead, keep it, or, for a time, increase it.

But suppose the period of calm after the violence of the injury to be well over-past—How does the right process of repair set in? Apparently, first of all, by the supply of blood to the injured part being increased.

The experiment, on the webs of frogs, to which I have already referred, have shown that, immediately after the infliction of an injury, the blood in the adjacent parts remains for some days quite stagnant; and we may believe the same occurs, but for a shorter time, in our own case. During this stagnation, materials may ooze from the vessels, enough to form the glazing of the wounded surfaces of certain parts; but before granulations can be formed, the flow of blood must again begin, and its supply must be increased by enlargement, and perhaps by

* One may sometimes observe a similar fact in the growth of granulations out of the very centre of the cut end of a divided tendon, while its margins are unchanged. The abundant growth of substance like brain covered with granulations, in cases of hernia cerebri, is of the same kind.

multiplication, of the vessels in the injured part. We cannot often see this increase so well in soft parts as in bone exposed after injury. If, in this condition, compact bone be closely watched, there may be seen, two or three days before the springing-up of granulations, rosy points or minute blotches, which gradually deepen in their hue, and become larger. From these, presently, granulations will arise. The same process may be well seen when a portion of the skull has been exposed, as by suppuration under the pericranium. In such a case, which I watched carefully, nearly one-third of the upper part of the skull was bared, and it became dry and yellowish, and looked quite lifeless; but after some days a few rosy points appeared on its surface, and these multiplied and enlarged, and from each of them granulations grew-up, till the whole surface of the skull was covered. I watched them nearly every day, and it seemed evident, at least to the naked eye, that, in all cases, an increased supply of blood preceded the production of the new material from which granulations were to be formed.

Doubtless just the same happens in soft parts as in bone; so that it may be stated, generally, that the first visible change that ensues after the period of calm,—the period of incubation, as it is called,—is an increased supply of blood to the parts in which repair is to ensue. This, probably, corresponds exactly with the increased afflux of blood which ensues in inflammation; and Mr. Travers' and other observations on the healing of the frog's web, make it nearly sure that this increased afflux is attended with slower movement of the blood, or at first even with stagnation of the blood in the minute vessels nearest to the cut edges or surface.

Of the force by which this increased afflux of blood is

determined, I believe that as yet no sufficient explanation can be rendered ; but the fact serves to show that the ordinary process of granulation is, in its commencement, morbid. It is beneficial, indeed, in its end or purpose, but is morbid in its method, being comparable with the process of inflammation more than with any of those that are natural to the body. The process of granulating displays, I think, two points of resemblance to inflammation, and of dissimilarity from natural processes : namely, 1st, that the increased quantity of blood in the part producing granulations moves more slowly than in health ; while in the naturally increased supply its movement is not retarded ; and 2dly, that the increased supply of blood precedes the increased production of material. For, in the discharge of natural functions, the increased supply of blood to a part appears always to be a secondary event, the consequence of some increase in the formation of the part. As, in the embryo, many parts form themselves before blood appears, and the growth of these and other parts always a little precedes the proportionate supply of blood to them ; so always, subsequently, the increase or diminution of growth, or any other organic act, appears to precede, by some small interval, the proportioned change in the supply of blood. But with unnatural and morbid processes it appears to be usually different : in these, with inflammation for their type and chief example, the increased afflux of blood precedes the increased production of material to be organized, and the decrease of blood precedes the decrease of organic processes.

That which next follows, after the increased afflux of blood, is the effusion of the material that is to be organized into granulations. This is added to, or, perhaps,

displaces, the glazing that already exists upon some surfaces ; and where none such exists, as on fat or bone, the new material is accumulated on the bare surface of the wound. No account of the process of effusion, so far as it is visible to the naked eye, can be better than Mr. Hunter's (iii. 491). "I have often been able," he says, "to trace the growth and vascularity of this new substance. I have seen upon a sore a white substance, exactly similar, in every visible respect, to coagulating lymph. I have not attempted to wipe it off, and the next day of dressing I have found this very substance vascular ; for by wiping or touching it with a probe it has bled freely. I have observed the same appearance on the surface of a bone that was laid bare. I once scraped off some of the external surface of a bone of the foot, to see if the surface would granulate. I remarked, the following day, that the surface of the bone was covered with a whitish substance, having a tinge of blue ; when I passed my probe into it I did not feel the bone bare, but only its resistance. I conceived this substance to be coagulating lymph thrown out from inflammation, and that it would be forced off when suppuration came on ; but, on the succeeding day, I found it vascular, and appearing like healthy granulations."

To this account, little can be added more than the microscope has shown. In the minute structure of granulations, or, at least, of such growths of new substance as present all the characters that we imply by that term,—the bright ruddy texture, the uniformly granulated free surface, the succulency and abundant supply of blood,—in these, we may discern two varieties, corresponding with the varieties of lymph that I have already spoken of. In subcutaneous injuries or diseases, granulations sometimes form which develop themselves into cellular tissue, through nucleated blastema. So I found in a case of simple frac-

ture in which the ends of the bone remained long disunited ; they were enclosed in a cavity formed by condensation of the surrounding tissues, but containing no pus, and were covered with a distinct layer of florid granulations. It was just such a case as that which Mr. Hunter had in view, and preserved,* as an instance of the formation of granulations without suppuration, in the repair of subcutaneous fractures and other injuries.

But in by far the greater proportion of cases, granulations are only formed in exposed injuries : and in these, they consist of cells that may develop themselves into fibro-cellular tissue : and of such as these I will now exclusively speak.

Cells upon cells, such as I have already described, (p. 183) are heaped-up together in a layer from half a line to two lines, or, rarely, more in thickness, without apparent order, and connected by very little intermediate substance. (Figs. 14 and 19.) Singly they are colourless ; but in clusters they are ruddy even independent of the bloodvessels. In granulations that are making healthy progress—in such as, after three or four days' growth, are florid, moist, level, scarcely raised above the surrounding tissues, uniformly granular, or like a surface of minute papillæ,—one can conveniently trace the cells in various stages, according to the position they occupy. The deeper-seated ones are always most advanced, and often much elongated, or nearly filamentous ; while the superficial ones are still in a rudimental state, or, near the edges of the granulating surface, are acquiring the character of epithelial cells.

The cellular tissue thus constructed by the development of the granulation-cells finally assumes all the characters of the natural examples of that tissue. Thus it is found in the thin layer of substance of which scars that are formed in the place

* College Museum, No. 16.

of granulating wounds, are composed. After some time, elastic tissue is mingled with the fibro-cellular; but this, as I have already said, appears to be effected by a later process. I found, in one case, no elastic tissue in scars that had existed, the one twelve months, the other eighteen months; but in scars several years old I have always found it.

The cuticle, also, that forms on granulations, gradually approximates more nearly to the perfect characters, and, like the fibro-cellular tissue that it covers, presents the interesting fact of adaptation to the purposes of the part on which it is placed. Thus, in granulating wounds or ulcers on the sole of the foot, one may often see that, from the first, the new cuticle is more opaque and thicker than it is on other parts, on which the natural cuticle, in adaptation to the protection required from it, is naturally thinner: and let it be observed that this peculiar formation of the new cuticle is in adaptation to conditions not yet entered upon. It justly excited the admiration of Albinus,* when he saw in the foetus, even long before birth, the cuticle of the heel and palm thicker than those of other parts; adapted and designed to that greater friction and pressure to which, in future time, they would be exposed. It is the same when, in adult life, new cuticle is to be formed on the same parts. While it is forming, all pressure and all friction are kept away, yet it is constructed in adaptation to its future exposure to them. Surely such a provision is, beyond all refutation, an evidence of design; and surely in this fact we may discern another instance of the identity in nature and in method of the powers that are put in operation in the acts of first construction and of repair.

But before I end this lecture, let me add, that although

* *Annotationes Academicæ.*

one may so clearly trace, in the development of granulation-cells, and in the end which they achieve by the formation of fibro-cellular tissue and cuticle, an imitation of the natural processes and purpose of the corresponding developments in the embryo, yet is there a remarkable contrast between them, in regard to the degrees in which they are severally liable to defect or error. We can scarcely find examples of the arrests or errors of development of mere structure in the embryo; but such events are quite common in the formation of granulations, as well as of all other new products. All the varieties in the aspect of granulating wounds and sores, which the practised eye can recognise as signs of deflection from the right way to healing, are so many instances of different diseases of the granulation-substance; diseases not yet enough investigated, though of much interest in the study of both the healing process and the organization of new products in inflammation.

A comparatively few observations enable one to trace morbid conditions of these new structures, closely answering to those long known in the older and more perfect tissues. Thus, one may find simply arrested development of granulations; as in the indolent healing of wounds and ulcers, whether from locally or generally defective conditions. Herein even years may pass, and the cells will not develop themselves beyond one or other of their lower forms. There is probably a continual mutation of particles among such cells, as in common nutrition; or they may increase, as in growth; but no development ensues, and the wound or the ulcer remains unhealed.

In other cases, the cells not only do not develop themselves, but they degenerate, becoming more granular, losing the well-marked characters of their nucleus, and acquiring all the structures of the pus-cell; thus are they

found in the walls of fistulæ and sinuses. Or, worse than this, the granulation-cells may lose all structure, and degenerate into a mere layer of debris and molecular substance. Thus they may be found on the surface of a wound for a day or so before death in exhaustion, or in erysipelas, or fever; and in this state they are commonly ejected when a granulating wound ulcerates or sloughs.

With more active disease, granulations become turgid with blood, or œdematous: such are the spongy masses that protrude beyond the openings leading to diseased bone. Or, they inflame; and abundant large inflammatory granule-cells are found among their proper structures. Or, they suppurate internally, and purulent infiltration pervades their whole mass.

All these are among the many hinderances to healing: these are the dangers to which the healing by granulations is obnoxious: it is the proneness to these things that makes it even slower and more insecure than, in its proper course, it might be. And these are all instances of a class of changes which it is most important to study for exactness in morbid anatomy,—I mean, the diseases of the products of disease.

LECTURE X.

THE PROCESSES OF REPAIR OF WOUNDS.

WITH the structural development of the granulation-cells into fibro-cellular tissue and cuticle, as described in the last lecture, there coincides a chemical change which seems to be the contrary of development; for the granulation-substance, being converted from albuminous into horny and gelatinous principles, becomes, in chemical composition, less remote than it was from the constitution of inorganic matter. At its first effusion, the reparative material has the characters of a fibrinous principle; afterwards, when in the form of granulations and of young fibro-cellular tissue, its reactions are so far altered that it presents the characters of pyine, a somewhat indefinite principle, yet an albuminous one; finally, in its perfect development, the new-formed fibro-cellular tissue is gelatinous, and the epithelium appears to be like other specimens of horny matter.

These changes are in conformity with what appears to be a general rule; namely, that structures which are engaged in energetic development, self-multiplying, the seat of active vital changes, are generally of the highest organic chemical composition; while the structures that are already perfect, and engaged in the discharge of functions such as are attended with infrequent changes of their particles, are as generally of lower composition. The much higher chemical development (if I may so call it) of the blood, than

of the greater part of the tissues that are formed from it, is a general instance of this : in it albumen and fibrine predominate, and there is no gelatine ; in the tissues gelatine is abundant, and fatty matter : and both these, through their affinities to the saccharine and oily principles, approach the characters of the lower vegetable and inorganic compounds.

The granulation-substance is a good instance in point : while lowly developed, but in an active vegetative life, it is albuminous ; when perfect in its development, its perfected structures are gelatinous or horny. In this state its particles have probably a longer existence : they exchange a brief life of eminence for longevity in a lower station.

I have spoken hitherto of the development of only those structures which form the proper material of granulations, and of the scars that remain after the healing of wounds. But, commensurately with these, blood-vessels, and, perhaps, also, nerves, are formed. Of these, therefore, I will now speak.

In the last lecture I referred to the changes that ensue in the circulation of a wounded part. At first, it appears that the blood stagnates in the vessels immediately adjacent to the wound. This is evident in the wounds made in frogs' webs, and is most probable in the case of wounds in our own tissues ; for else we could hardly understand the total absence of bleeding from a surface on which, as in every large wound, myriads of small vessels must be cut, and lie exposed. But after a time, of various duration in the different tissues, the movement of the blood is renewed, though not to its former velocity ; the vessels of the wounded parts enlarge, and they all appear more vascular. Then the material of granulations, already in part effused, accumulates, and very soon blood and blood-vessels appear in this material.

By what process are these new vessels formed? Mr. Hunter's opinion was, (and it is still held by many) that both the blood and its vessels form in the granulation-substance, as they do in the germinal area of the chick; and that, subsequently, they enter into communications with the vessels and blood of the part from which the granulations spring. This is certainly not proved; although the development of the new vessels is according to a method that is equally natural.

In embryos, we may discern three several modes according to which blood-vessels are formed,—a good example of the manifold ways by which, in development, the same end may be reached.* In the first and earliest method, they are constructed around the blood-corpuscles, which, being gradually developed from some of the embryo-cells, are laid-out in the plan of the earliest and simplest circulation of the blood. In this case, the vessels appear to be formed of the cells, or of the plasma which lies around the forming blood-cells, and gradually assumes the condition of a membrane, and is then developed into the more complex structures of the blood-vessels and the heart.

After this earliest period of embryo-life, it is probable that blood is never formed except within the vessels already constructed. It would seem as if none but the original embryo- or germ-cells could be directly transformed into blood-corpuscles; all those that are later made derive their materials through a process of gradual elaboration in lymph- or blood-vessels, to which process no resemblance can be discerned in the substance of granulations.

To increase the extent and number of vessels that must

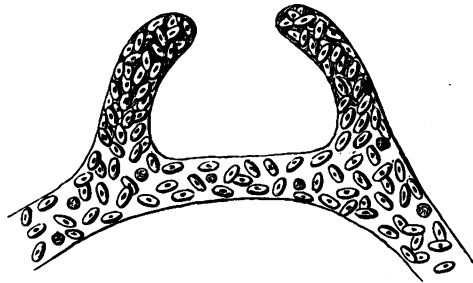
* They are described in Kirkes's *Physiology*, p. 661; and in the *Supplement to the Translation of Müller's Physiology*, p. 101. See also *Garlach; Gewebelehre*, p. 200.

be added in adaptation to the enlargement and increasing complexity of the embryo, two methods are observed. In one, primary cells, in the interspaces of vessels already existing, enlarge and elongate, and send out branches in two or more directions. These branches are hollow: and while some of them are directed into anastomosis with each other, others extend towards, and open with dilatations into, the vessels already formed and carrying blood. Then, these fine branches of each cell becoming larger, while the main cavity of the cell, from which they issued, attenuates itself, they are altogether transformed into a network of nearly uniform calibre, through which the blood, entering by the openings of communication with the older vessels, makes its way. Thus the wide network formed in the primordial circulation is subdivided into smaller meshes, and each part receives a more abundant supply of blood.

The other of these secondary modes of formation of new blood-vessels, is, I believe, the only mode in which blood-vessels are ever formed for granulations, or for superficial deposits of lymph, adhesions, and the like. The sketch is made from what may be seen in the growing

parts of the tadpole's tail, and it accords with what Spallanzani observed of the extension of vessels into the substance of the tail when being reproduced after excision. Mr. Travers*

FIG. 16.



and Mr. Quekett watched the same process in the new

* On Inflammation, and the Healing Process. See, also on a similar formation, Virchow in the Würzburg Verhandlungen, B. i. p. 301.

material formed for the filling up of holes made in the frog's web; and the same is indicated in the specimens illustrating the repair of similar wounds which are in the College, from the Museum of the late Dr. Todd, of Brighton. There is, I think, no sufficient reason to suppose that any other method prevails for the supply of blood-vessels to any granulations, or similar new productions. For, though the process in granulations or in lymph cannot be exactly watched during life, yet every appearance after death is consistent with the belief that it is the same as has been traced in the cases I have cited, and I have never seen any indications of either of the other methods of development having occurred.

The method may be termed that by *out-growth* from the vessels already formed. Suppose a line or arch of capillary vessel passing below the edge or surface of a part to which new material has been superadded. (Fig. 16.) The vessel will first present a dilatation at one point, and coincidentally, or shortly after, at another, as if its wall yielded a little near the edge or surface. The slight pouches thus formed gradually extend, as blind canals or diverticula, from the original vessel, still directing their course towards the edge or surface of the new material, and crowded with blood-corpuscles, which are pushed into them from the main stream. Still extending, they converge; they meet; the partition-wall, that is at first formed by the meeting of their closed ends, clears away, and a perfect arched tube is formed, through which the blood, diverging from the main or former stream and then rejoining it, may be continuously propelled.

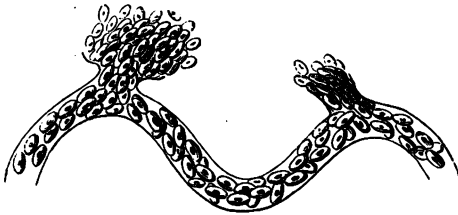
In this way, then, are the simplest blood-vessels of granulations and the like out-growths formed. The plan on which they are arranged is made more complex by the similar outgrowths of branches from adjacent arches, and their

mutual anastomoses ; but, to all appearance, the whole process is one of outgrowth and development from vessels already formed. And I beg of you to consider the wonder of such a process ; how, in a day, a hundred or more of such loops of fine membranous tube, less than 1-1000th of an inch in diameter, can be upraised ; not by any mere force of pressure, though with all the regularity of the simplest mechanism, but each by a living growth and development, as orderly and exact as that which we might trace in the part most essential to the continuance of life. Observe, that no force so simple as even that of mere extension or assimilation can determine such a result as this : for, to achieve the construction of such an arch, it must spring with due adjustment from two determined points, and then its flanks must be commensurately raised, and these, as with mutual attraction, must approach and meet exactly in the crown. Nothing could accomplish such a result but forces determining the concurrent development of the two out-growing vessels. We admire the intellect of the engineer, who, after years of laborious thought, with all the appliances of weight and measure and appropriate material, can begin at points wide apart, and force through the solid masses of the earth one tunnel, and can wall it in secure from external violence, and strong to bear some ponderous traffic ; and yet he does but grossly and imperfectly imitate the Divine work of living mechanism that is hourly accomplished in the bodies of the least conspicuous objects of creation—nay, even in the healing of our casual wounds and sores.

The wonder of the process is, perhaps, in some degree enhanced by the events that will follow what may seem to be an accident. When the new vessel has begun to project, it sometimes bursts ; and the diagram shows

what then will happen. I have to thank Mr. Quekett

FIG. 17.



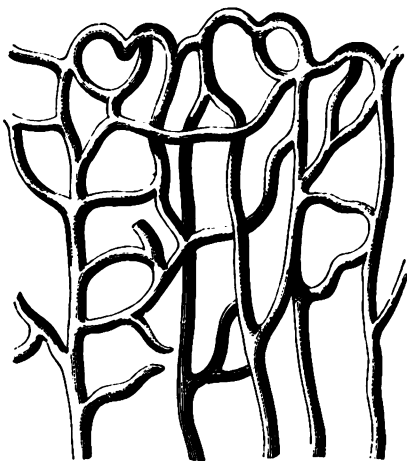
for the sketch, which he made while assisting Mr. Travers in the examinations already cited. The blood-corpuscles that issue from the ruptured pouch or di-

verticulum collect in an uncertain mass within the tissue, like a mere ecchymosis; but, before long, they manifest a definite direction, and the cluster bends towards the line in which the new vessel might have formed, and thus opens into the other portion of the arch, or into some adjacent vessel. For this mode of formation from vessels, the name of *channelling* seems more appropriate than that of out-growth; for it appears certain that the blood-corpuscles here make their way in the parenchyma of the tissue, unconfined by membranous walls. That they do so in a definite and purposive manner, though their first issue from the vessel has appeared so accidental, may be due to the fact that in the more regular development by out-growth, the cells of the parenchyma concur with the extension of the new vessels, by clearing away from them as they approach; so that, even before the out-growth, the way for it, or for its contents (should they happen to escape), is, in some measure, determined.

The occurrence of such a process of channelling as is here indicated loses all improbability, when we remember that in many insects and mollusca the blood habitually flows, in a considerable and important part of its course, through lacunæ, spaces, or channels without proper walls, such as are here supposed to exist only for a time.

The general plan of arrangement of the blood-vessels in granulations, represented in the adjoining sketch, agrees with this account of their development by out-growth.

FIG. 18.



Some of Sir A. Cooper's preparations in the Museum of the College* show how the new vessels extend from the parts on which the granulations lie, in lines directed vertically towards their surface, not often dividing, but communicating on their way by frequent transverse or irregular branches. Of these branches, some, probably, represent the loops or arches successively formed in the deepening layer of granulation-cells, while others must be formed by off-shoots from the sides and other parts of the several arches. Near the surface of the granulations, at a very little distance below the outermost layer of the cells, the vessels communicate much more frequently, and form their loops or terminal arches—arches of junction between the outgoing and the returning streams of blood.

On the same plan are formed the vessels of the walls of abscesses lined with granulations; but here (at least in the specimens I have been able to examine) the vertical vessels are not so long, and the whole number of vessels is generally greater. I believe the vessels of granulating ulcers are always similarly arranged; so they are represented by Mr.

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* Nos. 19, 20, 356.

Liston* in a common ulcer; so, also, Sir A. Cooper† described them in granulations from an ulcerated scirrhus cancer; and I have found the same general plan in the warty ulceration of soot-cancer on the scrotum.

The structure of the new vessels formed in granulations also agrees with the described mode of development. In the earliest period of their appearance they present no indication of being formed by fusion, or any transformation, of the granulation-cells, but consist of thin membrane, in which, if it be not quite simple, nuclei or cytoblasts are imbedded. These nuclei pass through stages of development, by narrowing and elongation, similar to that which I have described in the nucleated blastema; and thus they become like the pieces of flat fibre that one sees on the walls of the original vessels of the same size. Like them, also, they are arranged, some longitudinally, and some transversely to the axis of the vessels; and it is often noticeable, that the development of the tissues of the blood-vessels makes more progress than that of the granulation-cells which they subserve.

Respecting the purpose of the supply of blood thus sent to granulations, one traces, in the development of vessels, a series of facts exactly answering to those in ordinary embryonic development. Organization makes some progress before ever blood comes to the very substance of the growing part; for the form of cells may be assumed before the granulations become vascular. But, for their continuous active growth and development, fresh material from blood, and that brought close to them, is essential. For this, the blood-vessels are formed; and their size and number appear

* *Medico-Chirurgical Transactions*, vol. xxiii. p. 85.

† *Catalogue of the Pathological Museum of the College*, vol. i. p. 111.

always proportionate to the volume and rapidity of life of the granulations. No instance would show the relation of blood to an actively growing or developing part better than it is shown in one of the vascular loops of a granulation, imbedded, as this sketch shews it, among the crowd of living cells, and maintaining their continual mutations.

Nor is it in any case plainer than in that of granulations, that the supply of blood in a part is proportionate to the activity of its changes, and not to its mere structural development. The vascular loops lie imbedded among the simplest primary cells, or, when granulations degenerate, among structures of yet lower organization; and as

the structures are developed, and fibro-cellular tissue formed, so the blood-vessels become less numerous, till the whole of the new material assumes the paleness and low vascularity of a common scar. But, though the quantity of blood-vessels is determined by the state of the substance they supply, the development of their tissues has no such relation. It is often complete while the granulation-cells are rudimental, and remains long unchanged when they are degenerate. The fact may be regarded as evidence of the formation of the new blood-vessels by out-growth from the older ones; for it is not probable that well-developed blood-vessels and ill-developed granulation-cells should be formed out of the same materials at the same time.

FIG. 19.



Of the development of Nerves in granulations I know nothing ; I have never been able to see any in either granulations or cicatrices. The exquisite pain sometimes produced by touching granulations would indicate the presence of nerves : but it would be more satisfactory to see them ; for the force of contact, or the change that it produces, may be propagated through the layer of granulations, and stimulate the nerves beneath them, as contact with the exterior of a tooth excites the nerve-filaments in its pulp. The sensibility that granulations seem to have may, therefore, be really that of the tissues from which they spring.

Lymphatics do not exist in granulations. Professor Schroeder van der Kolk has demonstrated them in false membranes by mercurial injections :* but in a letter he tells me that they cannot, either by these or by any other means, be traced in either scars or granulations ; and, he adds, "they cannot be demonstrated in the skin, even in the healthy state, except in the scrotum."

The subject of suppuration should perhaps be considered now ; but I had rather defer it till I have spoken briefly of the two remaining modes of healing open wounds ; those, namely, by *secondary adhesion*, and by *scabbing*.

The healing by secondary adhesion, or union of granulations, has been long and often observed ; yet it has been only casually described, and having never been distinguished by a specific name, has not received that attention to which its importance in practice seems to entitle it. It occurs wherever surfaces of granulations, formed in the manner just described, well-developed, but not yet covered with

* Lespinasse, De Vasis Novis Pseudo-membranarum, figs. iii. iv.

cuticle, are brought into contact, and so retained at rest. As often as this happens, the cells of which the surfaces are composed adhere together; vessels passing through them form mutual communications; and the surfaces, before separate, are connected; out of the two layers of granulations, one is formed, which pursues the normal development into fibro-cellular tissue.

In all its principal characters, therefore, the process of secondary adhesion is like that adhesion for which, to mark at once their likeness and their differences, I have suggested the term of primary. In the primary adhesion, the layer of lymph, placed between the wounded and bare surfaces, is probably formed equally and coincidently from both; and, being developed in the same manner as the granulations, of which I have spoken, it probably receives vessels from both surfaces, and so becomes the medium through which the vessels communicate and combine the severed parts. In the process of secondary adhesion, the superficial cells on the surfaces of two layers of granulations are placed together, and receiving vessels from both combine them into one.

Mr. Hunter observed this process, and says of it—“Granulations have the disposition to unite with one another when sound or healthy; the great intention of which is to produce the union of parts, somewhat similar to that by the first intention, although possibly not by the same means.” And “I have seen two granulations on the head—viz. one from the dura-mater after trepanning, and the other from the scalp, unite over the bare bone which was between them so strongly, in twenty-four hours, that they required some force to separate them, and when separated they bled.”*

* Works, vol. iii. p. 493.

In illustration of this process he put up a preparation* which in his MS. Catalogue he described as "granulations under the skin in an abscess in the leg, which were opposed by others on the muscles, and which were to unite. Those under the skin only are saved and folded towards each other, to show the opposition of two granulating surfaces."

There are several circumstances in which the healing by secondary adhesion should be attempted. For example; after an ordinary amputation of the thigh, no immediate union, and no primary adhesion, took place, and the whole interior of the stump was granulating. Had it been, as the expression is, "left to granulate," or "to fill up with granulations," the healing process would have occupied at least a month or five weeks more, and would have greatly exhausted the patient, already weakened by disease. But Mr. Stanley ordered the stump to be so bandaged that the opposite surfaces of granulations might be brought into close contact: they united, and in a week the healing of the stump was nearly perfected.

In all such cases, and I need not say that they are very frequent, the healing by secondary adhesion may be attempted without danger, and often with manifest advantage.

Again: Mr. Hunter operated for hare-lip, and no primary adhesion of the cut surfaces ensued. He let them both granulate: then brought the granulations together, as in the common operation, and they united, and healed soundly.

Or, again: Mr. Skey, not long since, operated for fissure of the soft palate. The edges of the wounds sloughed and retracted, and the case seemed nearly hopeless; but he kept

* Pathological Museum of the College, No. 27.

in the sutures, and granulations sprang up from the edges of the cleft, after the separation of the sloughs : they met in the mid-space of the cleft, and coalesced, and formed a perfect scar.

Doubtless, cases like these are of no rare occurrence : but I am induced to mention them, as illustrations of a process of which the importance and utility are not generally considered, and which is rarely applied in practice.

In applying it, certain conditions are essential to success ; especially that—1st, the granulations should be healthy, not inflamed, or profusely suppurating, or degenerated, as those in sinuses commonly are ; 2dly, the contact between them should be gentle but maintained ; and perhaps they should be as much as possible of equal development and age.

The healing of wounds by scabbing may be regarded, as Mr. Hunter* says, as the natural one, for it requires no art. It is the method by which one sees nearly all open wounds healed in animals ; for in them, even in the warm-blooded, it is difficult to excite free suppuration from the surfaces of wounds : they quickly become coated with a scab, formed of the fluids that ooze from them and entangle dust and other foreign bodies ; and under such a scab the scar is securely formed.

In general, the scabbing process is effected by some substance which is effused on the surface of the wound, dries there, and forms a hard and nearly impermeable layer. The edges of this substance adhere over those of the wound, so as to form for it a sort of air-tight covering, under which it heals without suppuration, and with the formation of a scar, which is more nearly like the natural

* Works, vol. iii. 262.

parts than any scars formed in wounds that remain exposed to the air, and which does not, like them, contract, so as to produce deformity of the parts about it.

The scab may be formed of either dried blood, dried lymph and serum, or dried purulent fluid. Instances of the healing of wounds under dried blood are not rare. It is especially apt to occur in the cases of wounds in which a large flat surface is exposed, as after the removal of the breast with much integument. The most remarkable case of this kind is recorded by Mr. Wardrop.* The largest wounded surface he ever saw, remaining after the removal of a diseased breast, almost entirely healed under a crust of blood, which remained on for more than thirty days.† But the most common examples of healing under blood-scabs are in small wounds, such as are made in bleeding, or more rarely in some compound fractures. The excellent, though nearly obsolete, practice of laying on such wounds a pad of lint soaked in the blood, was a good imitation of the most natural process of their repair.

If a blood-scab be not formed over a wound, or if such an one have been detached after being formed, then at once a scab may be derived from the serum and lymph that ooze from the surface of the wound. Thus it is commonly with wounds in animals that are left to themselves, and in many small wide-open wounds in our own case. Thus, also, I imagine, the best healing of superficial burns and scalds is effected, when the exposed surface is covered with cotton-wool or other substance, which, as the oozing fluids become entangled with it, may help them to form a scab.

* In his Lectures on Surgery, in the *Lancet* for 1832-3, vol. ii.

† Mr. Henry Lee tells me that a similar case has occurred in his practice. An excellent instance of healing under blood-scabs is also related by Dr. Macartney (*Treatise on Inflammation*, p. 208).

At a yet later period, the pus produced from exposed granulating wounds may concrete on them, and they will heal under it excluded from the air. Such a process may also ensue in the healing of ulcers, and has been successfully imitated in Mr. Stafford's plan of filling deep ulcers with wax.* In any case, the healing process is probably just the same as that under scabs of blood or serum; but I believe it has not yet been exactly determined what are the changes that ensue in the surface beneath the scab. So far as one can discern with the naked eye, the wounded surface forms only a thin layer of cuticle on itself; no granulations, no new fibro-cellular tissue, appears to be formed; the raw surface merely skins over, and it seems to do so uniformly, not by the progressive formation of cuticle from the circumference towards the centre, as is usual in open wounds.

The healing of a wound by scabbing has always been thought a desirable process; and when one sees how quickly, by means of this process, wounds in animals are healed, and with how little general disturbance, one may well wish that it could be systematically adopted. But to this there seems some hinderance. Many surgeons have felt, as Mr. Hunter did, that the scabbing process should be permitted much oftener than it is, in the cases of both wounds and ulcers; but none have been able to lay down sufficient rules for the choice of the cases in which to permit it. Probably, the reason of this is that, at the best, in the human subject, the healing by scabbing is an uncertain process. When the scab is once formed, and the wound covered-in, it is necessary that no morbid exudation should take place. Whenever, therefore, inflammation ensues in a wound or sore covered with a scab, the exuded fluid, collecting under the

* On the Treatment of the Deep and Excavated Ulcer. 1829.

scab, produces pain, compresses the wounded surface, or forces-off the scab, with discomfort to the patient and retardation of the healing. I suspect that the many instances of disappointment from this cause have led to the general neglect of the process of scabbing in the treatment of wounds. The observance of perfect rest, and of the other means for warding-off inflammation, will, however, make it a valuable auxiliary in the treatment of wounds, especially of large superficial ones: in the treatment of small wounds, collodion appears sufficient to accomplish all that scabbing would do: and in deep wounds, fluid is too apt to collect under the scab.

Such are the several methods of healing observed after wounds of soft parts;* and in connection with them, two subjects remain to be considered, namely, the process of suppuration, and that of the perfecting of scars.

Respecting the process of suppuration, it cannot be necessary that I should give a minute account of pus, or of its general or chemical characters: I will rather endeavour to show its relations to the healing process, by illustrating the points of resemblance and of difference between it and the materials of which granulations are formed.

Let me remind you that the formation of granulations is not necessarily attended with the production of pus. I

* I have not been able to recognize what Dr. Macartney named the *modelling process*, as a method of healing distinct from that which ensues in the most favourable instances of healing by granulations. I have, therefore, not enumerated it among the modes of healing; yet it may occur in some conditions that I have not met with: I would not, with only my present experience, impute confusion to so good and independent an observer as Dr. Macartney.

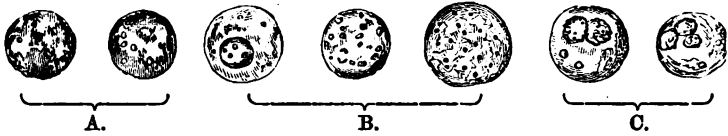
have already referred to this fact in speaking of the formation of subcutaneous granulations, such as are sometimes seen on the end of bones that do not unite, in the ordinary way, after simple fractures. Mr. Hunter also expressly describes these cases; and the same kind of granulations without suppuration may be sometimes seen springing from the ulcerated articular surfaces of bones, in cases of diseased joint without any external opening.

However, when granulations are formed on an open wound, there is always suppuration; *i. e.*, an opaque, creamy, yellowish-white or greenish-white fluid, pus, or matter, is produced on the surface of the granulations. If the surface be allowed to dry, the pus may form a scab: if it be kept moist, fresh quantities of pus are produced, till the surface of the granulations is covered with the new cuticle. Granulations that are skinned-over no longer suppurate.

The essential constituents of pus are cells, and the liquid (*liquor puris*) in which they are suspended. In pus produced during healthy granulation, no other material than these may be found. But, often, minute clear particles, not more than $\frac{1}{10000}$ of an inch in diameter, are mingled with the pus-cells, to which they seem to have some relation as rudiments. And, when the process deviates from health, we find not only variations in the pus-cells, but multiform mixtures of withered cells, molecular and fatty matter, free or escaped and shrivelled nuclei, blood-corpuscles, fragments of granular substance like shreds of fibrine, and other materials. All these indicate defects or diseases of pus, corresponding with those of the granulations to which I have already referred.

Pus-cells, in their ordinary state, are represented in the adjoining sketch.

FIG. 20.



As shown at A, they are spherical, or spheroidal, or even discoid bodies : the differences in shape depending apparently on the density of the fluid suspending them. In the same proportion as it becomes less dense, they tend to assume the more perfectly spherical shape. They have an uniform nebulous or grumous aspect ; distinct granules, more or less numerous, are commonly seen in them : and they appear more darkly nebulous and more granular in the same proportion as the fluid becomes more dense. Their usual diameter is from $\frac{1}{2500}$ to $\frac{1}{3000}$ of an inch. Sometimes a distinct, circular, dark-edged nucleus may be seen in the paler corpuscles ; and, more rarely, two or even three particles like a divided nucleus.

When, as in the corpuscles B, water is added to pus, it usually penetrates the cells, expanding them, raising up a distinct fine cell-wall, and separating or diffusing their contents. Sometimes the contents are uniformly dispersed through the distended cell, which thus becomes more lightly nebulous, or appears filled with a nearly clear substance in which minute particles vibrate with molecular movement, while in or near the centre a dark-edged well-defined nucleus may appear. Sometimes, while the cell-wall is upraised, the whole contents of the cell subside into a single ill-defined darkly nebulous mass, which remains attached to part of the cell-wall, looking like a nucleus, but differing from a true nucleus in the characters just assigned, as well as in the absence of the two or three shining particles like nucleoli. Lastly, a few pus-corpuscles appear

unchanged by the action of water : they seem to be merely masses of soft colourless substance having the shape and appearance, but not the structure, of cells.

When dilute acetic acid is added to pus (as in Fig. C), it produces the same effects as water, but more quickly, and with a more constant appearance of two, three, or four small bodies like nuclei. These bodies are remarkable, though far from characteristic, features of pus-cells. They are darkly edged, usually flattened, clear, and grouped, as if formed by the division of a single nucleus : and commonly each of them appears darkly shaded at its centre. When the acetic acid has been too little diluted, these bodies alone may be at first seen : for the cell-wall and the rest of its contents may be rendered so transparent as to be scarcely visible.

Such are the pus-cells found in healthy suppurating wounds. The liquor puris contains albumen, a compound called pyin, regarded by some as identical with that which Mulder described as tritoxide of protein, abundant fatty matter, and inorganic substances similar to those dissolved in the liquor sanguinis.

Pus not distinguishable from that of granulating wounds is formed in many other conditions ; as in inflamed serous and mucous cavities, and in abscesses. In these relations it will be considered in the lectures on Inflammation. But the histories of all cases of the formation of pus concur, with that of suppurating wounds, to the conclusion that pus may be regarded as a rudimental substance ill-developed or degenerated ; as a substance essentially similar to the materials of granulations, or of the lymph of inflammatory exudation, but which fails of being developed like them, or, after having been developed like them to a certain stage, degenerates.

To illustrate this relation between the pus and the

granulations of healing wounds, I may state that the last figure was copied from sketches that I made, at the same time, of some granulation-cells from the walls of a sinus, and some pus-cells from a healthily granulating wound. I chose those sources purposely, that I might be able to compare ill-developed granulation-cells with well-constructed pus-cells; and a comparison of them showed that, whether as seen without addition, or as changed by the action of water and acetic acid, they were not to be distinguished from one another. Had I not seen the vessels in the tissue that the granulation-cells formed, I might, in the first examination, have almost thought I was deceived in thinking they were not pus-cells. The six varieties of the appearances of the cells which are represented, might have been taken from either source; so might some other varieties: but these may suffice to show the apparent identity of structure between well-formed pus-cells and ill-developed or degenerate granulation-cells, such as are found in the walls of sinuses and the like half-morbid structures. I do not mean to say, generally, that granulation-cells and pus-cells cannot be distinguished; for between well-formed granulation-cells, such as are found in healing wounds, and any particles that are usually found in pus, certain distinctions are almost always manifest. The pus-cells are darker, more, and more darkly, granular, more various in size, and more various, not in shape, but in apparent structure, more often containing numerous particles, like fatty molecules, more rarely showing a nucleus when neither water nor acetic acid is added, and much more commonly showing a tripartite or ill-formed nucleus under the action of the acid. None, however, of these characters is indicative of essential difference; and between even the widest extremes there are all possible gradations, till distinction is impossible; so that when you place, as I

have often done, ill-developed or degenerate granulation-cells on one side of the microscope-field, and pus-cells on the other, there is not a form of corpuscle on the one which is not repeated on the other.

From this, one cannot but conclude that the cells of pus from wounds are ill-developed or degenerate granulation-cells. Some of them may be degenerate, *i. e.*, they may have been, as granulation-cells, attached for a time to the surface of the granulation-layer, and having lived their time, may, in ordinary course, have been detached and shed, as epithelial cells are from healthy surfaces. They may be thus detached after more or less degeneration, and hence may result some of the modifications that they present. But some pus-cells, I imagine (at least in the healing of wounds), may be ill-developed; that is, imperfectly formed of the material which exudes from the surface of the granulations, and which, being exposed to the air, or being too remote from the supply of blood, cannot attain its due development, and, in an imperfectly developed state, is soon cast off. It cannot but be that organizable matter is constantly oozing from such a surface as that of granulations; but the conditions into which it enters on that surface are such as are very likely to hinder any but the lowest or some imperfect organization.

The many characters of imperfection or of degeneracy that pus-cells show, accord with this view: such as the general imperfection of their nuclei; the frequent abundance of fatty-looking granules in them; the large quantity of fatty matter that analysis detects in pus; and the limitation of the cells to certain forms, beyond which they are never found developed, though none of these forms is more highly organized than that of the youngest or most rudimental granulation-cell.

A further confirmation of the opinion that pus-cells are

ill-developed or degenerate granulation-cells, is furnished in the cases, to which I shall hereafter refer, in which pus-cells are produced after, or together with, inflammatory lymph-cells; as in abscesses, inflamed membranes, and the like. Now such lymph-cells are not distinguishable in apparent structure from granulation-cells, and, like these, they may show every gradation of form to that of the pus-cell.*

But it is not only in the cells that we may trace this appearance of the degeneracy or incomplete development of pus. It is equally shown in the fluid part, or *liquor puris*, which, unlike the intercellular substance of granulations and inflammatory lymph, is incapable of organization, even when, by evaporation or partial absorption, it assumes the solid form. The liquor puris answers to the solid and organizable blastema of granulations; and as undue liquidity is among the most decided marks of ill-formed pus, so the abundance of the blastema, in proportion to the cells, is one of the best signs that granulations are capable of quick development.

These considerations may suggest, in some cases, the imperfection of the liquor puris; and an observation, which any one may easily make, seems to indicate that it may, in other cases, be the product of the degeneration and liquefaction of the solid blastema, as the pus-cells are, in the same cases, of the granulation- or inflammatory lymph-cells imbedded in it. If the formation of abscesses

* Valentin, Gerber, and many others, have held nearly the same view as this of the character of pus-cells; but I think they have not sufficiently, if at all, dwelt on the probability that some pus-cells are ill-developed, others degenerate from a previously higher development. The many varieties of form, and the many differences of the conditions in which they occur, may be thus explained. I think, too, that the characters of degeneracy, or imperfect development, in the liquor puris, have been too much overlooked.

be watched, one may see, on one day, a large solid and inflamed swelling, firm and almost unyielding, giving no indication of containing any collection of fluid; but, next day, one may detect in the same swelling the signs of suppuration; the border may feel as firm as before, but all the centre and the surface may be occupied with an ounce or more of matter. And observe, this change from the solid to the liquid state may have ensued without any increase of the swelling. Such an increase must have occurred had the pus been secreted in a fluid state into the centre of the solid mass: and the changes cannot, I think, be explained except on the admission, that the inflammatory product, which was effused and infiltrated through the tissue in a solid form, has been liquefied: its cells degenerating into pus-cells, its blastema into liquor puris.*

Can we assign any use or purpose to the process of suppuration? In the case of abscesses and acute inflammations we may discern no more of purpose than in any other disease. But, in the case of granulating wounds, the use commonly assigned to pus, that it serves as a protection to the granulations, is probably ascribed to it with reason. It does this even in the fluid state; but the devices of surgical treatment, having regard to present comfort, rarely let us see how much better it protects a wounded surface when, as in animals, it is allowed to dry into a scab.

Let us now consider the case of a wound completely healed, and the scar that occupies its place.

* Such a liquefaction is not that assumed in the older doctrines, which held that pus was partly formed of the dissolved materials of the original tissues. The original tissues doubtless remain, unless partially absorbed: yet there appears to be thus much of liquefaction in the formation of an abscess, that part of the inflammatory product, first formed as a soft solid, degenerates and becomes fluid.

It is hard to describe in general terms the characters of scars, varying as they do in accordance with the peculiar positions, and forms, and modes of healing of wounds. But two things may be constantly observed in them: namely, their contraction, and the gradual perfecting of their tissues.

A process of contraction is always associated with the development of granulations. Mr. Hunter has minutely described it, and preserved several specimens to illustrate it: among which are two stumps,* in which its occurrence is proved by the small size of the scars in comparison with that of the granulating surfaces which existed before them. This healing of stumps, especially after circular amputations, will always show the contraction of the granulations, even before the cicatrix is formed; for one sees the healthy skin drawn in and puckered over the end of the stump, before any cuticle is formed on the granulations, except perhaps on the very margin. And many injuries, but especially burns, show the contraction of the scar continuing long after the apparent healing is completed.

To what may we ascribe this contraction of both the granulations and the scars? It has been regarded as the result of some vital power of contraction; and possibly it may be so in some measure. Yet, on the whole, it seems rather to be the necessary mechanical effect of the changes of form and construction that the parts undergo. The same change ensues in the organization of inflammatory products: as, *e. g.*, in false membranes, indurations, thickenings of parts, and the like consequences of the exudation and organization of lymph.

Now, in all these cases, the form of the cell, while developing itself into a filament, is so changed that it will occupy

* Nos. 28 and 29 in the Museum of the College.

less space. The whole mass of the developing cells becomes more closely packed, and the tissue that they form becomes much drier; with this, also, there is much diminution of vascularity. Thus, there results a considerable decrease of bulk in the new tissue as it develops itself; and this decrease, beginning with the development of the granulation-cells, continues in the scar, and, I think, sufficiently accounts for the contraction of both, without referring to any vital power.

The force with which the contraction is accomplished is often enormous. One sees its result in the horrible deformities that follow the healing of severe burns. Deep scarred and seamed depressions, even of the bones, may be produced by the contraction of granulations and scars over them. The whole process shows the error of such expressions as "filling-up with granulations," commonly applied to deep healing wounds, as if granulations increased in thickness till they attained the level of the upper margins of deep hollows. The truth is, that, even in the deepest open wounds, the granulation-layer is, as usual, from one to three lines thick; and that, when such a wound grows shallower in healing, it is not by the rising of the granulations, but by the lowering of its margins. The granulations and the scars of deep open wounds remain alike thin and depressed.

The improvement and perfecting of the tissue of the scar is, again, a very slow process. It is often thought remarkable that nerves and some of the higher tissues should require so long time for their repair; but scarcely less is necessary for the perfecting of a common scar. The principal changes by which it is accomplished include the removal of all the rudimental textures, the formation of elastic tissue, the improvement of the fibrous or fibro-cellular tissue, and of the new cuticle, till they are almost

exactly like those of natural formation ; and the gradual loosening of the scar, so that it may move easily on the adjacent parts.

All these changes are very slowly accomplished. One sees their effects, it may be, only after the many years in which, as it is said, the scars of childhood gradually wear out ; *i. e.*, in which the new-formed tissues gradually acquire the exact similitude of the old ones. Thus, the remains of the rudimental cellular tissue, imperfectly developed, may be found in apparently healthy scars of ten months' duration. After second operations, in which the scar of some former wound was removed, I have still found imperfectly developed granulation-cells in the tissue of the scar. Elastic tissue, also, I think, is not commonly formed in the first construction of a scar, but appears in it sometimes as much as twelve months after its first formation, and then gives it the common structure of the mixed fibro-cellular and elastic tissues which exist in the cutis.

But, an occurrence which may appear more singular than this slow perfecting of the tissues, is, in all good scars, as they are called, that gradual loosening of the tissue which at first unites the scar to all the adjacent parts. Thus, in such a wound as is made for tying a deep artery, or in lithotomy, at first the new tissue, the tissue of the scar, extends down to the bottom of the wound, equally dense in all parts, and fastening the skin to the parts at the very deepest portion of the wound. But after a time this clears up. The tissue of the scar in the skin becomes more compact and more elastic ; but that beneath it becomes looser and more like natural cellular tissue ; and the morbid adhesions of one part to another are freed. So, after injuries or diseases followed by scars about joints, the stiffness depending on the adhesion of the scar to the deeper tissues gradually decreases : and, so, in like manner,

the scars of burns often become gradually and of themselves more pliant, and the parts which they held become more freely moveable, though sometimes scarcely seeming to change for a year after the first healing of the injury.

Now, in all this gradual return of tissues to the healthy state, we may trace, I think, a visible illustration of the recovery from the minute changes of disease. In all there is a gradual approach of the new particles that are successively produced, to a nearer conformity with the specific character of the parts they should replace, till repair becomes almost reproduction. And how, let me ask, can all this be reconciled with any theory of assimilation? How can assimilation alter the characters of a scar? how make one part of it assume one character, and another part a character quite different, till, at length, that which looked homogeneous, as a mass of new-formed tissue, acquires, in separate parts, the characters of the several tissues in whose place it lies, and whose office it is destined, though still defectively, to discharge?

LECTURE XI.

THE REPAIR OF FRACTURES.

THE necessity, which I have felt in the preceding lectures, of describing the healing process as it is observed in a few typical examples, is increased, when I come to the consideration of the repair of fractures. A volume would not suffice for all that should be said of it; for there are no examples of the reparative process which present so many features of interest as this does, whether we consider its practical importance, or the wide field which it offers alike for the science and for the art of surgery, or the abundant illustrations of the general principles of recovery from injury which are present in every stage of the process, or the perfect evidences of design which it displays, of design that seems unlimited in the variety and point with which it is adapted to all the possible diversities of accident. To consider the repair of fractures completely, in any of these views, would be far beyond my purpose, and farther beyond my ability. I shall therefore limit myself almost entirely to an account of the repair of the simple fractures of long bones. What is true of this will be so nearly true of the repairs of other fractures, that a few words may suffice in reference to the chief modifications of the process in them. Moreover, I shall in general describe only what occurs in the adult human subject.

The injury inflicted in the fracture of a long bone is

rarely limited to the bone. The two or more fragments, driven in opposite directions, penetrate the adjacent tissues, wounding and bruising them, and giving rise to bleeding of various amount. Provided all these injuries are subcutaneous, and the air has no access to the damaged parts, their repair is perfectly, though slowly, effected. It is not unfrequent, in recent fractures, to find portions of muscle or other soft parts completely crushed by the bones, or even, in minute fragments, enclosed in the reparative material or the inflammatory exudations; and yet, when similar fractures are examined a year or more after their occurrence, the tissues round the bone appear quite normal in their structure, however disturbed they may be in their relations.

The periosteum is rarely much damaged in fractures of long bones. It is seldom stripped off the broken ends. Commonly, it is cleanly rent across at the same level as the bone is broken, and maintains its close union, having only its fibres somewhat frayed or pulled from their natural direction. Sometimes, indeed, it remains entire, even in extensive fractures; and in this case, thickening, it contributes to the security of the repair of the injury.

The extravasation of blood about fractures is not only uncertain in amount, but unequal in the several tissues. Its abundance in the subcutaneous tissue is often so remarkable, as to be among the useful signs for diagnosis, in cases of doubtful fracture near joints; but in the deeper soft tissues less blood is shed; and, commonly, in the periosteum, near the broken ends of the bone, only a few spots of blood are seen. I have already spoken (p. 177) of the manner in which the extravasated blood is disposed of; and since it rarely appears to take part in the reparative process,

I shall make no further mention of it.

Some days elapse, after a fracture, before any clear marks of a reparative process can be found. An early consequence

of the injury appears to be the exudation of a small quantity of inflammatory lymph; so that the cellular tissue in and near the seat of injury appears more succulent than is natural, being infiltrated with a serous-looking fluid, in which are cells like those of granulations or lymph.

In bad cases, this exudation may increase, and add to the swelling that is often seen to augment in the second or some later day; but, in better instances of repair, and when the parts, even though much injured, are kept at rest, I think the inflammatory exudation usually ceases after the second or third day, and that, then, some days pass before the proper reparative material is produced.* The state of the injured parts during this period of calm, or of incubation, is probably like that observed in wounds of soft parts (page 203). Its duration is uncertain, but I think, in the adult, is rarely less than one week or more than two.

In this long period of inaction we find the first contrast between the repairs of fractures in man, and in the animals that have been used for experimental inquiry into the process, as dogs, rabbits, pigeons, and others. In any of these, an abundant reparative material will be produced, and organized into cartilage or bone, in a time little longer than elapses before the first commencement of the process in a man.† We cannot, therefore, from the rapidity of repair in any lower animals, form any just calculation of its rate of progress in ourselves.

The proper reparative process, commencing after this period of rest, may usually be divided into two chief parts; namely, the process of uniting the fragments, and that of shaping or modelling them and their combining substance.

* More concerning this inflammatory exudation will be related in the account of the repair of tendons in the next lecture.

† See Nos. 418, 419, 420, in the Museum of the College; and Series iii. Nos. 69, 70, 71, &c., in that of St. Bartholomew's.

The uniting and the modelling parts of the process are so different in nature and in time, that they may well be considered separately. They are comparable with the forming and the subsequent perfecting of the scars of wounded soft parts; and in the union of fractures, even more evidently than in any other instance of repair, we may note how safety is first provided for, then symmetry; how the welfare of the individual is first secured, and then the conformity of the repaired part to the typical or specific form: for the modelling scarcely begins before the uniting is completed.

The union of fractures is commonly effected by the organization of new material connecting the fragments. Sometimes, indeed, immediate union occurs. When portions of bone are placed and held in exact apposition, they may be united without any new material being formed for their connection; a continuity of tissues and of blood-vessels being restored, as in the cases of healing by immediate union of soft parts. But this is rare, and has not yet been sufficiently studied.

The material deposited for the more usual method of repair of simple fractures,—the callus, as it is called, when it has become firm or hard,—is, I think, in the first instance, not visibly different from the material formed for the repair of other subcutaneous injuries. Its peculiarity is shown in the direction and end of its development; and, in this respect, the repair of fractures supplies an extreme case of the variety of ways through which the same end of development may be attained.

In its first production, the reparative material is a structureless, or dimly shaded, or granular substance, like fibrine; or, perhaps at a later period, it is ruddy, elastic, moderately firm and succulent, like firm granulation-substance. Of the manner in which it is placed, in the space and in the tissues around or between the fragments to be connected, I will

speak presently. At first, it has none of the firmness belonging to the "callus:" this, however, it soon attains, as it makes progress towards being transformed into bone. Its ossification, as I have said, may be accomplished through several transitional forms of tissue, which might be distinguished as so many varieties of callus, if the term be worth retaining. It may become, before ossifying, either fibrous or cartilaginous, or may assume a structure intermediate between these; and, in either of these cases, ossification may ensue when the previous tissue is yet in a rudimental state, or may be delayed till the complete fibrous or cartilaginous structure is first achieved.

I cannot tell the conditions which will determine, in each case, the route of development towards bone that the reparative material will take; nor in what measure the differences that may be observed are to be ascribed to the seat or nature of the injury, or to the condition of the patient. All these things have yet to be determined; and I believe that years of patient and well-directed investigation will be requisite for them. I can do little more than point out the modes in which the ossification may be accomplished.

And, first, it may be accomplished through perfect fibrous tissue. Thus I found it in a case of fracture of the lower part of the femur after six weeks, and in a fracture of the radius after about nine weeks; thus, too, I think, whatever new bone is formed after fractures of the skull is developed; and thus one may find, in the neighbourhood of fractures and other injuries of bone, ossifications of interosseous fibrous membranes, and of the tissue of the periosteum, or just external to it.*

* The thin plate of bone which closes in the exposed medullary canal of the end of a fractured long bone, where one fragment overlaps another, will usually, I think, present a good example of ossification of fibrous tissue.

But, secondly, the new bone may be formed by ossification of the fibrous tissue in a rudimental state. And this rudimental state may be that of either nucleated cells or nucleated blastema. Through nucleated cells, as the embryo-forms of fibrous tissue, bone is formed when granulations or inflammatory exudations ossify. The process may be often seen in the union of compound fractures, or of simple ones when much inflammation has been excited. But, best of all, though here only for illustration of what may occur in fractures, the ossification of nucleated cells, in granulations, may be observed, when bone is formed in the mushroom-shaped mass of granulations that is protruded through the medullary canal of a bone sawn across in an amputation.* In all these cases there appears to be a direct transformation into bone, without the intervention of either cartilage or perfect fibrous tissue.

The ossification of nucleated blastema, such as I have described as a rudimental form of fibrous tissue, may also be seen in simple fractures; and my impression is, that it is an ordinary mode of ossification in simple fractures of adult long bones that unite well and quickly. In such a case, in a fracture of the tibia of five weeks' date, I found, in long-continued examinations, that the bone is formed without any intermediate state of cartilage; a finely and very closely granular osseous deposit taking place in the blastema, and gradually accumulating so as to form the delicate yet dense lamellæ of fine cancellous tissue. The nuclei of the blastema appeared to be enclosed in the new-forming bone, and I thought I could trace that they became the bone-corpuscles; but I could not be sure of this.

Thus, the new material produced for the repair of fractures may be ossified through an intermediate fibrous stage.

* College Museum, Nos. 552, 553.

In other instances it may pass through a cartilaginous stage. In animals, perfect cartilage, with its characteristic homogeneous intercellular substance, its cells, and all the characters of pure foetal cartilage, may be produced. Through the ossification of such cartilage, Miescher* and Voetsch,† and others, describe the repair of fractures as accomplished in dogs, pigeons, and other animals. I have not yet found the very same process in the human subject; but I should think it would occur in favourable instances of simple fracture in children. In youths and adults, I have found only varieties of fibrous cartilage; and these have presented numerous gradations from the fibrous towards the perfect cartilaginous structure. In different specimens, or sometimes even in different parts of the same, the reparative material has displayed, in one, fibrous tissue, with a few imbedded corpuscles, like the large nearly round nuclei of cartilage-cells; in another, a less appearance of fibrous structure, with more abundant nucleated cells, having all the characters of true cartilage-cells; and in a third, a yet more nearly perfect cartilage.‡

Through any of these structures the reparative new bone may be formed. It may be formed, first, where the reparative material is in contact with the old bone, and thence extending, it may seem as if it grew from the old bone; or

* *De Inflammatione Ossium*, 1836.

† *Die Heilung der Knochenbrüche*, 1847.

‡ I do not describe the minute methods of ossification occurring in the callus, or reparative material; for my opportunities of studying it in man have been too few for me to conclude from: and, although I have seen nothing opposed to the belief that the normal methods of ossification are imitated, yet the process seems capable of so many modifications that I think it would not be safe to adapt, unconditionally, to the case of the reparative material in man, such conclusions as are drawn from the normal ossification of his skeleton, or from the ossification of the reparative material in lower animals.

it may be formed in the new material, in detached centres of ossification, from which it may extend through the intervening tissues, and connect itself with the old bone. (See figs. 21 and 23.)

The new bone, through whatever mode it is formed, appears to acquire quickly its proper microscopic characters. Its corpuscles or lacunæ, being first of simple round or oval shape, and then becoming jagged at their edges, subsequently acquire their canals, which appear to be gradually hollowed out in the preformed bone, as minute channels communicating with one or more of the lacunæ. The laminated canals for blood-vessels are later formed. At first, all the new bone forms a minutely cancellous structure, which is light, spongy, soft, and succulent, with a reddish juice rather than marrow, and is altogether like foetal bones in their first construction. But this gradually assimilates itself to the structure of the bones that it repairs; its outer portions assuming a compact laminated structure, and its inner or central portions acquiring wider cancellous spaces, and a more perfect medulla. It acquires, also, a defined periosteum, at first firm, thin, and distinctly lamellar, and gradually assuming toughness and compactness. But, in regard to many of these later changes in the bonds of union of fractures, there are so many varieties in adaptation to the peculiarities of the cases, that no general account of them can be rendered.

A subject of chief interest in the repair of fractures is the position of the reparative material, and in relation to this we find a greater difference than any yet mentioned between the processes traced respectively in man and in the animals submitted to experiments.

There are two principal methods according to which the reparative material, or callus, may be placed. In one, the broken ends or smaller fragments of the bone are completely

enclosed in the new material; they are ensheathed and held together by it, as two portions of a rod might be by a ferrule or ring equally fastened around them both. In such a case, illustrated by fig. 21, the new material, surrounding the fracture, has been usually called "provisional callus," or "external callus:" but the term "ensheathing callus" will, I think, be more explanatory. In the other method (as in figs. 22 and 23), the new material is placed only between those parts of the broken bone whose surfaces are opposed; between these it is inlaid, filling the space that else would exist between them, or the angle at which one fragment overhangs another, and uniting them by being fixed to both. Reparative material thus placed may be called "intermediate callus." In either method (as in figs. 21 and 22), there is usually some reparative material deposited in and near the broken medullary tissue; and this may be still named "interior callus."

The method of repair with an ensheathing or provisional callus is rarely observed in man, but appears to be frequent in fractures of long bones in animals.* From these it has been admirably described by Dupuytren and others. The

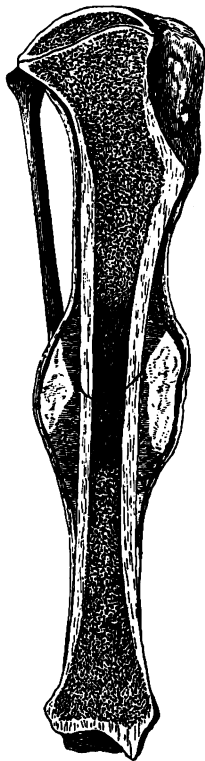
* Even in animals it is not constant. To obtain what would be called good specimens of provisional callus, the injuries must be inflicted upon young animals, and among these I cannot but suspect that particular instances have been selected for description; those in which less callus was formed having been put aside as imperfect instances of repair, though, in truth, they may have displayed the more natural process. Such good specimens are, in the Museum of the College, Nos. 418 to 426; and in that of St. Bartholomew's, Ser. iii., 69, 70, 71, 96, 81, 82, 92, 106. Fig. 21 is drawn from No. 96. It is very desirable to obtain examinations of fractured long bones recently united in young children; for it is probable that in these the process would be very like that described from the experiments on animals. No opportunity for such an examination has yet occurred to me.

chief features of the process are as follows (omitting dates, which have not been ascertained in man, and cannot well be calculated for him) :—

In the simplest case, when the fragments (as represented in this dog's tibia : fig. 21) lie nearly in apposition, and nearly

correspond, the reparative material accumulates at once around and within them, and in any interspaces that may be left between them. That around them, that is, the ensheathing callus, forms most quickly and in greater abundance, and lies chiefly or solely between the wall of the bone and the periosteum, which is thus lifted up from the wall, the blood-vessels that passed from it into the bone now passing to their destinations through the callus. The distance from the broken ends to which the callus extends up each frag-

FIG. 21.



ment is uncertain : in the long bones of dogs, and the ribs of men, it is usually about half an inch. The thickness of the callus is greatest at a little distance from the plane of the fracture : exactly in that plane it is usually less thick than either above or below ; so that, even when it is ossified, it is often marked with a slight annular constriction.

The interior callus fills up the spaces in the cancellous tissue, extending in the medullary canal of each fragment to a distance somewhat short of that to which the ensheathing callus reaches. At the end of each fragment there is usually an abrupt contrast between the firm reparative material that forms this interior callus, and a softer substance, like that of granulations, which remains between the fragments even till the callus without and within is quite ossified. As the section drawn in fig. 21 shows, the reparative material is abundant and well developed both around and within the fragments: but between them, *i. e.*, in the plane of the fracture, it is sparingly formed and soft, so that the fragments, if the ensheathing callus were removed, would be no longer held together; they are, in fact, combined long before they are united.

The ossification of the ensheathing callus is accomplished chiefly or solely by outgrowth of bone from the fragments on which it is placed. Here, also, the same method of progress is observed, in that the formation of new bone extends gradually towards that part of the callus which exactly corresponds with the plane of the fracture. This part of the callus is last ossified; but, at length, its ossification being complete, the fragments are combined by and within a sheath or ferrule of new bone. The interior callus, ossifying at about the same time, consolidates the cancellous tissue of the fragments, and, at a later period, unites them. The walls remain still longer disunited. The ossified callus is, indeed, sufficient to render the bone fit for its office, but it retains the nearly cancellous tissue of new bone, and it is still only provisional: for when the walls of the fragments are themselves united, and their continuity is restored, all, or a part, of the external callus is removed, and the cancellous tissue loses its solidity by the removal of the internal callus.

Such is the process of repair with an ensheathing callus. It is, as I have said, usual in animals ; but in man I have never seen its occurrence as a natural process in any bones but the ribs. In these it may be traced as perfectly as I have described it from the instances of repaired fractures of long bones in the rabbit and dog. Sometimes, indeed, a similar process occurs in other human bones : I have seen it in the clavicle and humerus ;* but in both these cases the more proper mode of repair had been disturbed by constant movement of the parts, and in the humerus the process had manifest signs of exaggeration and disease.

The normal mode of repair in the fractures of human bones is that which is accomplished by "intermediate callus." The principal features of difference between it and that just described are, (1) that the reparative material or callus is placed chiefly or only between the fragments, not around them ; (2) that, when ossified, it is not a provisional, but a permanent, bond of union for them ; (3) that the part of it which is external to the wall of the bone is not exclusively, or even as if with preference, placed between the bone and the periosteum, but, rather, in the tissue of the periosteum, or indifferently either in it, beneath it, or external to it.

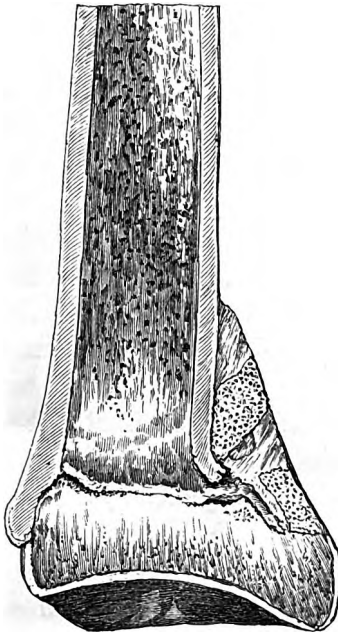
When the fragments are placed in close apposition and correspondence, they may, I believe, be joined by immediate union ; but if this do not happen, a thin layer of reparative material is deposited between them ; it does not, in any direction, exceed the extent of the fracture ; neither does it,

* Museum of St. Bartholomew's, Ser. iii. 92, 65, and 66. The clavicle was broken twelve weeks before death ; but the fracture was not detected, and the fragments were allowed to move unrestrained. The humerus was taken from a man who died some weeks after the fracture, and whose arm had, for several days after the injury, been the seat of severe spasms. See Mr. Stanley's "Illustrations of Diseases of Bones," Pl. xxiii. fig. 3.

in more than a trivial degree, occupy the medullary canal ; but, being inlaid between the fragments, and there ossifying, it restores their continuity. The process may be compared with that of union by primary adhesion.

When, as more commonly happens, the fragments, though closely apposed, do not exactly correspond, but, at certain parts, project more or less one beyond the

FIG. 22.



other, the reparative material is, as in the former case, inlaid between them, and, to a slight extent, in the medullary canal : but it is also, in larger quantity, placed in the angles at which the fragments overhang one another. Its position is, in these cases, well shown in the specimens drawn in the 22d and 23d figures. In the fractured radius* (fig. 22) the carpal portion, laterally displaced, projects beyond the radial margin of the upper and impacted portion ; and the angle between them is exactly filled, without being surpassed, by a wedge-shaped

mass of reparative material. So, but less perfectly, is the angle on the ulnar side. In the fractured femur† (fig. 23),

* Museum of St. Bartholomew's, Ser. iii. No. 94.

† The same Museum, Ser. iii. No. 103.

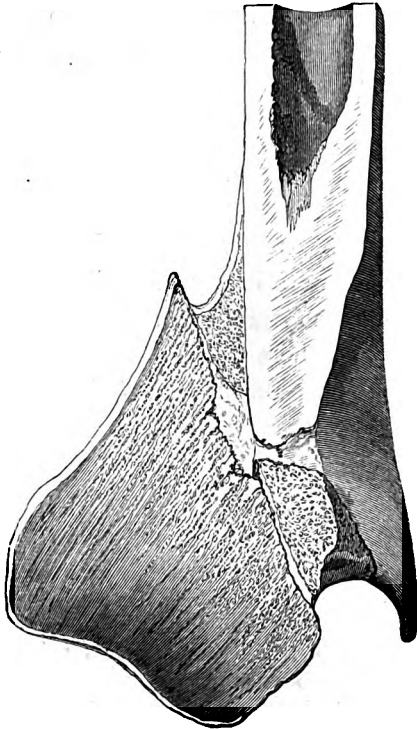
with great displacement of the fragments, the same rule is observed: the interspace between the fragments, and parts of the angles at which the one projects beyond the other, are filled with partially ossified reparative material. In neither case is there an ensheathing callus; in neither is any reparative material placed on that aspect of the one fragment which is turned from the other.

Lastly, when the fragments neither correspond nor are apposed, when one completely projects beyond or overlaps another, and when, it may be, a wide interval exists between them, still the reparative material is only placed between them. It just fills the interval; it does not even cover the ends of the fragments, or fill any part of the medullary canal: much less does it enclose both the ends

of the mutually averted surfaces, as the provisional callus would in a similar fracture in a dog or a rabbit; it passes, bridge-like, from one fragment to the other, and thus, when ossified, combines them. Thus it appears in the fractured femur, part of which is represented in fig. 24.*

The three instances which I have cited, of different rela-

FIG. 23.



* Museum of St. Bartholomew's Hospital, Ser. iii. No. 98.

tive positions of the fragments, may suffice as examples of classes in which nearly all simple fractures of long bones might be described. But, whether the displacement were like either of these, or of any other kind, I have seen no examples (other than the exceptions already mentioned) in which the reparative material has been placed according to a different method.* It is always an intermediate bond of union; it is inlaid between the fragments; and when formed in largest quantity, is only enough to smooth the chief irregularities, and to fill-up the interspaces and angles between them. And, regarding the particular position which it may in each case occupy, I do not know that it can be more exactly described, than by saying, that it is deposited where it is most wanted for the strengthening of the bone; so that, wherever would be the weak part, if unhealed, there is the new material placed, in quantity as well as in position just adapted to the exigencies of the case, and restoring, as much as may be, the original condition and capacities of the bone.

* I exhibited at this lecture all the specimens of fractures examined within six months of the injury that are contained in the Museums of the College and St. Bartholomew's; and they all, with the exceptions already mentioned, exemplified this account of the repair by intermediate callus, and of the absence of provisional or ensheathing callus. They included a radius, four weeks after the fracture; another, four or five weeks; a tibia, five weeks; a femur, six weeks; another of the same date; a third, about eight or nine weeks; a radius, of somewhat later date; a tibia, eight weeks; a fibula, eleven weeks; a tibia, twelve weeks; a tibia, sixteen weeks after the injury; and many others of various but unknown dates, all in process of apparently natural repair. Since the lecture was given, the description has been confirmed by many examinations by myself and others. It is similarly approved by specimens in which the union has been long completed; but less satisfactorily, because it might be said that we cannot tell how much callus may have been removed.

If, now, it be inquired why this difference should exist in the corresponding processes in man and other animals, I believe it must be ascribed principally to two causes, namely, the quietude in which fractures in our bones are maintained, and the naturally greater tendency to the production of new bone which animals always manifest. Even independently of surgery, in the case of fractures of the lower extremity, the human mode of progression almost compels a patient to take rest: and in fractures of the upper extremity, the circumstances of human life and society permit him to do so far more than other animals can. The whole process of repair is, therefore, more quietly conducted; and, as we may say, there is comparatively little need of the strength which the formation of provisional callus would give a broken limb.

The exceptions to the rule, of difference in the repair of human bones and those of animals, confirm it as thus explained; for they are found in the ribs, which are certainly never kept at rest during all the time necessary for repair after fracture, and in bones of which, from various causes, the repose of the fragments has been disturbed, or which have been the seats of disease, with inflammatory deposit, during or subsequent to the reparative process.

The comparative restlessness of animals is, however, I think, not alone sufficient to account for all the difference in the processes. The remainder may be ascribed to their greater tendency, in all circumstances, to the formation of new bone. Not in fractures alone, but in necrosis this is shown. It is very rarely that such quantities of new bone are formed in even children, as are commonly produced after necrosis of the shafts of bones in dogs or other animals; nor is there in the human subject any such filling up of the cavities from which superficial sequestra have been

separated, as the experiments of Mr. Hunter showed, after such exfoliations from the metatarsal bones of asses.*

It remains, now, that I should describe the later part of the repair of fractures,—that which consists in the shaping or modelling of the fragments and of their bond of union.

Omitting the removal of the provisional callus, where such an one has been formed, this modelling is best observed when there has been much displacement of the fragments. In these cases, the chief things to be accomplished are, 1st, the removal of sharp projecting points and edges from the fragments; 2dly, the closing or covering of the exposed ends of the medullary tissue; 3dly, the forming a compact external wall, and cancellous interior, for the reparative new bone; and lastly, the making these continuous with the walls and cancellous tissue of the fragments.

The first of these is effected by the absorption of the offending points and angles; and an observation sent to me by Mr. Delagarde tells much of the process: "A patient in the Exeter Hospital had a bad comminuted fracture of the leg, and a long spike of the tibia, including part of its spine, could not be reduced to its exact level, but continued sensibly elevated, though in its due direction. At the end of five weeks (union having taken place) the end of the spike began to soften; at six, it was quite soft and flexible, like a thin cartilage; at the conclusion of the

* Museum of the College, Nos. 641 to 653.

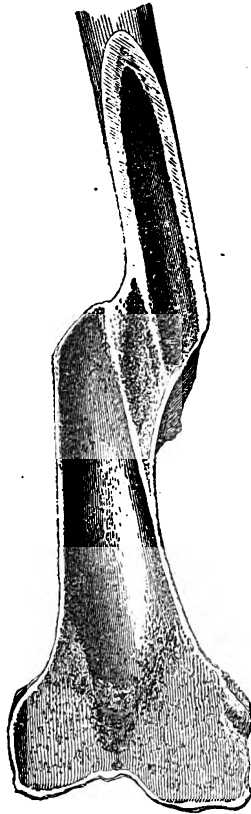
The denial of the formation of an ensheathing callus in the repair of fractures is sometimes met by the statement that such a callus can be often felt during life. The deception is produced either by thickening and induration of the soft parts around the fracture; or by the two overlapping ends of the fragments being grasped at once; or, much more rarely, by new bone accumulated about the fragments in consequence of inflammation.

seventh week it was blunt and shrunken. Six months later, the cartilaginous tip had disappeared, and the spike was rounded-off."

I have since, in a similar case, seen the same process repeated. Both cases seem to show that the absorption of the bone is accomplished, as Mr. Hunter described it in cases of necrosis, by removing first the earthy matter, and then the softened remains of animal substance.

The closing or covering-in of the parts of the broken medullary tube, which are exposed in fractures with much displacement, is slowly accomplished by the formation of a thin layer of compact bone, like that which covers the cancellous tissue at the articular ends of bones. It is well

FIG. 24.



shown in the original of the 24th figure.* In a fracture of the femur, after six weeks, I have seen the exposed medullary tube covered-in with a thin fibrous membrane, tense like a drum-head, new-formed, and continuous with the periosteum. The permanent closure

* From the Museum of St. Bartholomew's, Ser. iii. No. 98.

appears to be effected by the ossification of such a membrane; and the new bone becomes smoothly continuous with the rounded and thinned broken margins of the walls of the old bone. So are the ends of stumps covered-in; and neither in these nor in fractures have I seen new bone extending into the medullary canal, as if formed by the ossification of an internal callus.

The same sketch shows the nearly completed formation of distinct walls and medullary tissue in the bridge of new bone connecting the two fragments of the femur. At an earlier period we may be sure that all this new bone was soft and cancellous; it has now acquired the textures proper to the bone which it repairs, and, as if to complete its conformity with the structures among which it was thus, by accident, introduced, the process was begun by which the new and the old compact and medullary tissues would become respectively continuous. Already those parts of the walls of the shaft that intervene-like partitions, separating the new from the old medullary tissue, are thin, uneven on their surfaces, and in their interior half-cancellous. At some later time they would, probably, have been reduced to mere cancellous tissue, and the repair of the fracture would have been completed, crookedly indeed, but with unbroken continuity of tissue.

To adapt the foregoing account to the case of compound fractures, it is, I believe, only necessary (so far at least as the normal process of repair is concerned) to say that the reparative material is more mingled with products of inflammation; that that part of it which is formed within reach of the air, or in a suppurating cavity, is developed to bone through the medium of granulations, like those formed in open wounds of soft parts; and that the whole process of repair is, generally, slower, less secure, and more dis-

turbed by morbid growths of bone, and other effects of what has been named "ossific inflammation."

The data, at present collected, concerning the times in which the several parts of the reparative process are usually completed after fractures of adult human bones, are not sufficient for more than a general and approximate estimate. They may be thus generally reckoned. To the second or third day after the injury, inflammatory exudation in and about the parts; thence to the eighth or tenth, seeming inaction, with subsidence of inflammation; thence to about the twentieth, production of the reparative material, and its gradual development to its fibrous or cartilaginous condition; thenceforward its gradual ossification, a part of the process which is, however, most variable in both its time of commencement and its rate of progress, and which is, probably, rarely completed before the ninth or tenth week, although the limb may have long previously recovered its fitness for support or other use. From this time the rate of change is so uncertain, that it is impossible to assign the average time within which the perfection of the repair is, if ever, accomplished.

The consequences of failure in the process of repair may be illustrated by what I have described as its normal course. In a large part of the cases of ununited fracture the fragments are connected by fibrous or fibro-cartilaginous tissue, inlaid between them. Such is the defective union of most cases of fracture of the neck of the femur within the capsule, and of the olecranon and the patella when their fragments are not held close; and such a defect may occur in any long bone. It is an example of arrested development of the reparative material; and may be, in this respect, compared with the condition of granulations whose cells persist in their rudimental form. Every other

part of the process may be complete; but this part fails, and the fragments are combined by a yielding, pliant, and almost useless bond.

In other cases, the failure seems to occur earlier. No reparative material is formed, and the fragments remain quite disunited. This may be the result of accidental hinderances of the normal reparative process: but it sometimes appears like a simple defect of formative power; a defect which, I believe, cannot be explained, and which seems the more remarkable when we observe the many changes which may, at a later time, be effected, as if to diminish the evil of the want of union. Thus, commonly, the ends of bones thus disunited become covered with a thin layer of fibrous tissue, polished as if with a covering of epithelium, and as smooth as an articular surface: similar smooth linings form in the cavities that enclose them; the tissues immediately around them become condensed and fibrous; and thus, at length, the ends of the fragments are brought to the imitation of a joint, in which they may move without mutual injury. Or else, in the place of such a false joint, the end of each fragment has a kind of bursal sac formed on it, protecting the adjacent parts from injury in its movements. But, much as may be thus accomplished, new bone is not spontaneously produced. As the result of disease, it may be formed; and in this case it is often formed uselessly, and without evident design, in heaps or nodules about the ends of the fragments; yet it is of such disease that surgery may often make happy use when it can excite inflammation of the fragments, and so hold them close that the new bone may grow between or around them, and fasten itself to both.*

* It will diminish the defects of the foregoing description of the repair of fractures, which I have drawn almost entirely from my own observations, if I subjoin a list of the works especially or chiefly

devoted to this subject, in which the reader may find the best help to a larger knowledge of the subject.

- Dupuytren: *Exposé de la Doctrine de M. Dupuytren sur le Cal, par Sanson.* In *Journ. Univ. des Sciences Médicales*, t. xx.
- Breschet: *Recherches. . . sur la Formation du Cal: Thèse.* Paris, 1819.
- Howship: *On the Union of Fractured Bones.* *Med.-Chir. Trans.* vol. ix.
- Miescher: *De Inflammatione Ossium eorumque Anatome.* Berlin, 1836.
- Flourens: *Sur le Développement des Os et des Dents.* Paris, 1842.
- Lebert: *Sur la Formation du Cal.* In his *Physiologie Pathologique*, t. ii. Paris, 1845.
- Voetsch: *Die Heilung der Knochenbrücke.* Heidelberg, 1847.
- Stanley: *Illustrations of the Effects of Disease and Injury of the Bones*, p. 27. 1849.
- Malgaigne: *Traité des Fractures et des Luxations*, t. i. Paris, 1847.
- Dusseau: *Onderzoek van het Beenweefsel en Verbeeningen in zachte Deelen.* Amsterdam, 1850.

LECTURE XII.

HEALING OF INJURIES IN VARIOUS TISSUES.

THIS last lecture on the process of repair I propose to devote to the consideration of the modes of healing of several different tissues ; modes which, although they be all consistent with what has been said of the general rules and methods of the healing process, yet present each some peculiarity that seems worthy of observation.

And first, (though it matters little which I begin with), of the healing of wounds and other injuries of cartilage.

There are, I believe, no instances in which a lost portion of cartilage has been restored, or a wounded portion repaired, with new and well-formed permanent cartilage, in the human subject. When a fracture extends into a joint, one may observe that the articular cartilage remains for a long time unchanged, or else has its broken edges a little softened and rounded-off. In one case, I saw no other change than this in six weeks : but at a later period the gap is filled with a tough fibrous tissue ; or rather, the gap becomes somewhat wider and shallower, and the space thus formed is so filled-up.

The excellent researches of Dr. Redfern* have ascertained the method of this process in incised wounds of the arti-

* Anormal Nutrition in Articular Cartilages : Edinburgh, 1850. And, On the Healing of Wounds in Articular Cartilages : in the Monthly Journal of Medical Science, Sept. 1851.

cular cartilages of dogs. As showing the slowness of the repair, he found in one instance, in which he made three incisions into the cartilage of a patella, and two into that of the trochlear surface of the femur, that no union had taken place in twenty-nine weeks. No unusual cause for the want of union had been apparent, yet a reparative process had but just commenced. In another case, twenty-five weeks and four days after similar incisions, he found them completely and firmly united by fibrous tissue formed out of the substance of the adjacent healthy cartilage. The cut surfaces of the cartilage were very uneven, and were hollowed into small pits, produced by the half-destroyed cartilage-cells, the former contents of which were now lying on the surface. No evident change had taken place in the texture of the cartilage at a little distance from the cut surfaces, except that here and there the intercellular substance presented a fibrous appearance. The substance uniting the cut surfaces consisted of a hyaline, granular, and indistinctly striated mass, in which were numbers of rounded, oblong, elongating, or irregularly-shaped corpuscles. A nucleated fibrous membrane, formed by the conversion of the superficial layers of the cartilage bordering the wounds, was continuous with their uniting medium. "The essential parts of the process [of union of such incised wounds] appear to be," Dr. Redfern concludes, "the softening of the intercellular substance of the cartilage, the release of the nuclei of its cells, the formation of white fibrous tissue from the softened intercellular substance, and of nuclear fibres by the elongation of the free nuclei."

Such a process has peculiar interest as occurring in a tissue which has no blood-vessels, and in which, therefore, the reparative material is furnished by transformation of its own substance, not by exudation from the blood. In the same view the results of inflammation of articular cartilage will have to be particularly noticed.

In membraniform cartilages that have perichondrium, the healing process is, probably, in some measure modified; a reparative material being furnished, at least in part, from the perichondrial vessels. The cartilaginous tissue was less changed than in Dr. Redfern's cases, in an example of wounded thyroid cartilage that I examined. A man, long before death, cut his throat, and the wound passed about half an inch into the angle of his thyroid cartilage. In the very narrow gap thus made, a gap not more than half a line in width, there was only a layer of tough fibrous tissue; and with the microscope I could detect no appearance of a renewed growth of cartilage. The edges of the cartilage, to which the fibrous tissue was attached, were as abrupt, as clean, and as straight as those would be of a section of cartilage just made with a very sharp instrument. The cut cartilage was unchanged, though the union between it and the new-formed fibrous tissue was as close and as firm as that of the several parts of a continuous tissue. The perichondrium on both sides was equally firmly attached to the fibrous bond.

In some instances (but I suppose in none but those of cartilages which have a natural tendency to be ossified in advancing years) the fractures of cartilage may be united by bone. This commonly happens in the fractures of the costal cartilages; and it has been noticed in fractures of the thyroid cartilage. The union of a fracture of the cartilaginous portion of a rib is usually effected, as that of one in the osseous portion is, by an enclosing ring of bone, like a provisional external callus; and the ossification extends to the parts of the cartilage immediately adjacent to the fracture.*

* Museum of the College, No. 377; and of St. Bartholomew's, Ser. iii. Nos. 48, 73. Numerous examples of the partial repair of larger injuries of articular and other cartilages will be found in Hildebrandt's *Anatomic*, B. i. p. 306.

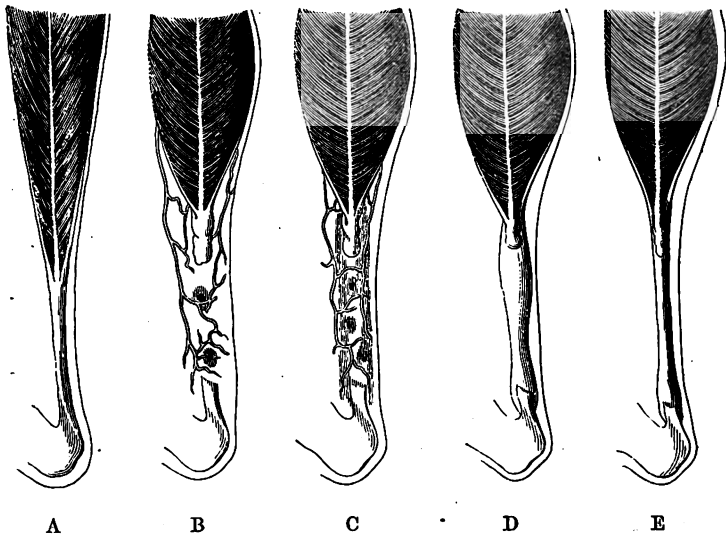
Healing of Tendons.—I have already often referred to the phenomena that follow the division of tendons by subcutaneous and by open wounds ; but the practical interest of the subject will justify my giving a connected account of the process, as I observed it in a series of numerous experiments performed, with the help of Mr. Savory, on rabbits from three to six months old. Such experiments are, I know, open, in some measure, to the same objection as I showed in the last lecture to those on fractures in the lower animals ; but the few instances in which examinations have been made of human tendons, divided by subcutaneous section, have shown that the processes in man and in animals are not materially different. The chief differences are, we may believe, that, as in the repair of bones, the production of reparative material is more abundant, and its organization more speedy, in animals than in man.

I have already, in the second lecture, stated generally the differences in the several consequences of open and subcutaneous wounds. In the case of divided Achilles-tendons, the disadvantages of open wounds, *i. e.* of wounds extending through the integuments over and on each side of the tendon, as well as through it, were as follows :—1. There were always more inflammation in the neighbourhood of the wound, and more copious infiltration of the parts, than in a subcutaneous division of the tendon in the same rabbit ; 2. Suppuration frequently occurred, either between the retracted ends of the divided tendon, or beneath its distal end ; 3. The skin was more apt to become adherent to the tendon, and so to limit and hinder its sliding movements, when the healing was completed ; 4. The retracted ends of the tendon were more often displaced, so that their axes did not exactly correspond with each other, or with that of the reparative bond of union.

Such mishaps were often observed in the open wounds,

but were rare after the subcutaneous operations. In the cases of open wounds, they were avoided as often as the wound through the integuments healed quickly; and, whenever this happened, the case proceeded like one in which the subcutaneous division had been made. It was evident that the exposure of the wounded parts to the air did little

FIG. 25.



harm, if it was continued for only a few hours; a fact that may be usefully remembered when operations must be performed on tendons which it is not convenient to divide unseen.

These same cases of speedy healing of the opening in the integuments served to show, that it is unimportant for the healing of divided Achilles-tendons, whether the cellular sheath or covering of the tendon be divided or not. In all

the cases of open division in these experiments, it was completely cut through ; yet, when the external wound healed quickly, the union of the divided tendon was as speedy and as complete as in any case of subcutaneous division in which it might be supposed that the sheath of the tendon was not injured.

I will describe now the course of events after subcutaneous division of the Achilles-tendon ; stating only what was generally observed, and illustrating it, as far as may be, with the annexed diagram (Fig. 25), in which, as in longitudinal sections, A may represent the natural condition of the tendon and its muscles, and the succeeding figures the effects of its division and the successive stages of its repair.*

At the instant of the division, the ends of the tendon separate to the distance of nearly an inch, the upper portion of the tendon being drawn up the leg by the action of the gastrocnemius and soleus muscles (B). The retraction is comparatively much greater than is usual in operations on the human Achilles-tendon ; for where these are done, the muscles are seldom capable of strong or extensive contraction. It is in all cases to be remembered that the separation is effected entirely by the withdrawal of the upper portion of the tendon : the lower, being not connected with muscle, remains with its end opposite the wound. To this we may ascribe the general fact that the reparative process is more active, and the inflammatory process less so, at the upper than at the lower portion of the tendon : for the

* The account here given agrees in all essential respects with that by Lebert, in his *Abhandlungen der prakt. Chirurgie*, p. 403. Neither do the accounts materially differ, except in being less minute, which are given by Von Ammon (*De Physiologia Tenotomiæ*), Duval (*Bull. de l'Acad. Royale de Médecine*, 1837), and Duparc (*Nederlandsch Lancet*, 1837).

latter lies in the very centre of the chief inflammatory action; while the former is removed far from it, being drawn away, at once from the seat of the injury, and from even the slightest exposure to the air.

I have already said that very little blood is effused in the subcutaneous operations. Commonly, only a few blotches of extravasation appear in and near the space from which the upper part of the tendon is retracted (B). The first apparent consequence of the division of the tendon is the effusion of a fluid or semi-fluid substance, which, like the product of common inflammation, quickly organizes itself into the well-known forms of lymph- or exudation-cells. These, speedily becoming more distinctly nucleated and elongated, undergo the changes which I mentioned in describing the development of cells in granulations. The exuded lymph makes the tissues at and near the wound succulent and yellow, like parts infiltrated in anasarca. The blood-vessels near the divided tendon enlarge, as in an inflamed part, and appear filled with blood (B, C). The exudation, together with the enlargement of the vessels, swells the parts, so that the skin is scarcely at all depressed between the separated ends of the tendon. But in well-made subcutaneous sections, this inflammatory product is of small amount, and takes, I believe, little or no share in the healing of the injury; for the exudation ceases after the first twenty-four hours, and I think that its cells are not developed beyond the state in which they appear spindle-shaped. I have never seen indications of their forming filaments of cellular or fibrous tissue.

In rabbits, forty-eight hours usually elapse before there are distinct signs of the production of the proper reparative material. This is deposited in the fibro-cellular tissue that lies between and close round the separated ends of the tendon, as well as in the interspaces of the tendinous fas-

ciculi of those ends. It thus swells-up the space between the separated ends, and makes the ends themselves larger, and somewhat ruddy, soft, and succulent. Some portion, at least, of it being deposited where the inflammatory effusion was, one finds their constituents mingled; but I believe that, while the proper reparative material develops itself, the product of the inflammation is either arrested in its development, or even degenerates; its cells shrivelling and gradually wasting.

I need not now describe the mode of development of the reparative material provided for divided tendons: for I have taken it as a typical example of the development of lymph into nucleated blastema, and thence into fibrous tissue (p. 186). To the naked eye it appears after three days as a soft, moist, and greyish substance, with a slight ruddy tinge, accidentally more or less blotched with blood, extending from one end of the tendon to the other, having no well-marked boundary, and merging gradually into the surrounding parts (c). In its gradual progress, the reparative material becomes commensurately firmer, tougher, and greyer, the ruddiness successively disappearing from the circumference to the axis: it becomes, also, more defined from the surrounding parts, and, after four or five days, forms a distinct cord-like vascular bond of connection between the ends of the tendon, extending through all the space from which they have been retracted, and for a short distance ensheathing them both (D, E).

As the bond of connection thus acquires toughness and definition, so the tissue around it loses its infiltrated and vascular appearance: the blood-vessels regain their normal size, the inflammatory effusion clears up, and the integuments become looser, and slide more easily. In every experiment, one finds cause for admiration at the manner in which a single well-designed and cord-like bond of union is

thus gradually formed, where at first there had been an uniform and seemingly purposeless infiltration of the whole space left by the retraction of the tendon.

With the increase of toughness, the new substance acquires a more decidedly filamentous appearance and structure. After the fourth day, the microscope detects nuclei in the previously homogeneous fibrine-like reparative material; and after the seventh or eighth day there appear well-marked filaments, like those of the less perfect forms of fibrous tissue. Gradually perfecting itself, but with a rate of progress which becomes gradually less,* the new tissue may become at last, in all appearance, identical with that of the original tendon. So it has happened in the valuable specimens presented to the Museum of the College by Mr. Tamplin.† They are the Achilles-tendon and the tendons of the anterior and posterior tibial muscles of a child nine months old, in whom, when it was five months old, all these tendons were divided for the cure of congenital varus. The child had perfect use of its feet after the operation, and, when it died, no trace of the division of any of the tendons could be discerned even with microscopic aid.

In the instances of divided human tendons, less retraction, I have already said, takes place than in those of lower animals. The connecting bond is therefore comparatively shorter; and it is yet more shortened when, like a scar, it contracts as it becomes firmer. It is impossible, therefore,

* One may remark this as a general fact, that when once the reparative process has commenced, much more appears to be done in it in the first few days than in any equal subsequent period of time. It may be another instance justifying the general expression, that production is easier than development or improvement, and that the earlier or lower developments require less organizing force than the higher or later.

† Nos. 358, 359, 360.

to say what length of new material was, in this case, formed into exact imitation of the old tendon. But, however little it may have been, such perfect repair as these specimens show is exceedingly rare. More commonly the differences between the original tendon and the new substance remain well-marked. The latter does not acquire the uniform arrangement of fibres, or the peculiar glistening thence accruing to the normal tendons: it is harder and less pliant, though not tougher; its fibres appear irregularly interwoven and entangled, dull-white, like those of a common scar. And these differences, though as time passes they become gradually less, are always seen when a longitudinal section is made from behind, through both the ends of the tendon and the new substance that ensheaths and connects them. In such a section (as in fig. 25, E), one sees each of the retracted ends of the divided tendon preserving nearly all its peculiar whiteness, only somewhat rounded or mis-shapen, swollen, and imbedded in the end of the new substance, which is always greyer, or less glistening, and looks less compact and regular. In the retracted ends of the tendon, one may discern the new substance mingled with the old and interposed between its fasciculi, with which one may believe it is connected by the finest dove-tailing.*

The strength, both of the new substance itself, and of its connection by intermingling with the original substance, is worthy of remark. To test it, I removed from a rabbit an Achilles-tendon, which had been divided six days previously, and of which the retracted ends were connected

* The appearances are shown in specimens in the College Museum, Nos. 348 to 354; and in those from the experiments on rabbits in the Museum of St. Bartholomew's.

by a bond of the size and texture usual at that period of the reparative process. I suspended from the half-section of this bond gradually increased weights. At length it bore a weight of ten pounds, but presently gave way with it: yet we may suppose the whole thickness of the bond would have borne twenty pounds. In another experiment, I tried the strength of a bond of connection which had been ten days forming: this, after bearing suspended weights of twenty, thirty, forty, and fifty pounds, was torn with fifty-six pounds. But surely the strength it showed was very wonderful, when we remember that it was not more than two lines in its chief diameter; and that it was wholly formed and organized in ten days, in the leg of a rabbit scarcely more than a pound in weight. With its tenacity it had acquired much of the inextensibility of the natural tendon. It was indeed stretched by the heavy weights suspended from it, yet so slightly that I think no exertion of which the rabbit was capable would have sufficed to extend it in any appreciable degree.

The Healing of Muscles, subcutaneously divided, presents many things exactly similar to those just described as observed in the healing of tendons similarly divided, and the structure of the connecting reparative bond is of the same kind; new muscular fibres, I believe, are never formed. But, in the experiments which I made on the triceps extensor brachii, and the tibialis anticus of rabbits, there was always observed a peculiar inversion, subsidence, or *tucking-in* of the muscular fibres at the divided part; so that nearly all the fasciculi directed their cut ends towards the subjacent bone or fascia. Thus it sometimes appeared to happen that, though the retracted portions of the muscle were imperfectly united, yet the action of the muscle was

not lost ; for one or both its ends, acquiring new attachments to the subjacent parts, could still act, though with diminished range, upon the joint over which its fibres passed.

In general, it appeared that the reparative material was less quickly produced than after division of the tendons ; but this might be because of the greater violence inflicted in the operation, more than because of the structure of the divided parts. The usual method and end of the development of the reparative material were the same as after division of the tendons ; and at length, but always, I think, more slowly than with them, the ends of the retracted portions became inclosed in a tough fibrous bond of union.

After the formation of this bond, the healing of divided muscles is improved, both by the clearing up of the surrounding tissues infiltrated with inflammatory products, and by the contraction of the new bond, which thus draws together the retracted portions of the muscle, so that they may nearly coalesce. Thus, in a man who had cut his throat long before his death, and had divided the left sterno-hyoid, omo-hyoid, and sterno-thyroid muscles, I found that the ends of these muscles, though they must at first have retracted considerably, had all been drawn to attachments on the cricoid cartilage, over which their several portions nearly united.

The *Healing of Injured Arteries and Veins* is commonly a more complicated process than those already described, on account of the changes that ensue in the blood that is stagnant within, or shed around, the injured vessel.*

* Nearly all that follows relates to the healing of wounds of arteries. The process in veins appears to be essentially the same, but more quickly accomplished. See Stilling: "Die natürlichen Prozesse bei der Heilung durchschlungener Blutgefäße." Eisenach, 1834, p. 147 and 289.

Small wounds of either arteries or veins may heal by immediate union, or primary adhesion, as those of any other tissue may, and the blood shed into the adjacent tissues may be absorbed as from a common ecchymosis. An artery divided in only part of its circumference, although it may be for a time contracted, yet does not remain so; neither is it commonly, in such a case, obstructed by clot within its canal. Hence, after such wounds, the pulse in the distal or lower part of the artery is often unaffected. After the first outrush of blood, some that remains extravasated among the tissues usually clots, and covers the wound in the artery; but the closure is often ineffectual, or only for a time, and fresh bleedings ensue, either increasing the accumulation of extravasated blood, or pushing-out the clots already formed. In this way, with repeated hæmorrhages at uncertain intervals, the wound in an artery is often kept open, and at the end of two or three weeks may show no trace of healing, but, rather, appear widened and with softened everted edges. In such a case, it is possible that the wound in an artery may still heal by granulations, either rising from its edges or coalescing over it from adjacent parts; but the event is too unlikely to justify the waiting for its occurrence, if there be opportunity for surgical interference.

In the case of an artery divided quite across, three chief things are to be considered; namely, the natural immediate arrest of the bleeding, the closure of the two orifices, and the disposal of the blood that may become stagnant at and near the ends of the divided vessel.

The bleeding is arrested, mainly, by the contraction of the muscular coat of the artery. Stimulated by the injury and by exposure to the air, and relieved from much of the pressure of the blood, whose onward course is less resisted, the muscular tissue of the divided artery contracts

and closes, or, at least, diminishes, the canal. In some instances the contraction is narrowly funnel-shaped, and the end of the artery may be open, while, at a little distance within, its canal is closed or much narrower. In some, the exterior layers of the muscular fibres seem to contract rather more than the interior, and the end of the artery appears prominent or pouting. Many, perhaps trivial, differences of this kind may be noticed in different arteries cut across in amputations.

The retraction of the divided artery within its sheath, or among the adjacent tissues, assists to stay the bleeding, by giving opportunity for the blood to become diffused, as it flows through the tissues that collapse over the end of the artery before it closes. But the degree to which this retraction can take place is very uncertain. It depends chiefly on the laxity or the closeness of the attachment of the artery to the surrounding tissues, and on the extent to which they with it are divided, and with it are capable of retraction. In amputations, one sees many differences in these respects. Arteries divided close to ligamentous parts and the origins of muscles appear much retracted, because the tissues about them are scarcely at all drawn back; so it is in amputations just below the knee: but those that are divided where there is much cellular tissue, or where muscles are far from their origins, as in the middle or lower part of the forearm, appear less retracted, because these surrounding parts are retracted as much or more than they. In like manner, arteries from which branches are given off just above the place of division retract less than others, the branches holding them in place.

Equally various is the degree in which the bleeding from a wounded artery is arrested by the blood collecting around it, and in front of its orifice. It depends mainly on the degree of retraction of the artery, and on the facility with

which the blood can escape through the external wound. It is assisted, in case of large hæmorrhage, by the weakening of the action of the heart, and, perhaps, by the readier coagulation of the blood which ensues in syncope.

The efficacy of these means for the arrest of bleeding from all but the principal arterial trunks, is evident enough immediately after the amputation of a limb. However many arteries may need ligature, they are probably not more than a tenth of those that were just now traversed by quick streams of blood. The rest are already closed by their own muscular action, needing no assistance from a diminished action of the heart, or the effusion of blood around them.

I know no observations showing the method of healing and permanent closure of the small arteries that thus spontaneously cease to bleed. All the accurate inquiries that I am aware of relate to the closure of the torn umbilical arteries, which have hardly a parallel in other vessels, or else to the more complicated cases of large arteries on which ligatures have been tied, or which have been closed by some artificial means, such as the "Durchschlingung" of Stilling; a defect much to be regretted, since the ligature, or any similar means, introduces such a disturbance into the process of repair, as makes it a morbid process, however advantageous its end may be. Indeed, when a divided artery is tied, the injury to be repaired is not that of the wound, but that of the ligature; an injury in which a bruised wound dividing the middle and internal coats of the artery, a bruise with continued compression of its external coat, and the continued presence of a foreign body, are superadded to the injuries which preceded the application of the ligature.

For simplicity's sake, let us consider the repair of such an injury in only that part of an artery which is above the

ligature, *i. e.* nearer to the heart. The changes in the part beyond the ligature are, according to Stilling, the same, but more quickly accomplished.

Now, in this repair, three parts are chiefly concerned; namely, (1) the injured walls of the vessel at and immediately adjoining the ligature; (2) the part of the vessel between the ligature and the first branch above it, through which the blood can flow-off; and (3) the blood which, within the same part of the vessel, *i. e.* between the ligature and the first branch nearer to the heart, lies nearly stagnant. The healing of the artery may indeed be accomplished without the help of this blood, but certain changes in it commonly concur with the rest of the process.

(1.) The injured walls of the vessel, and the tissue immediately around them, inflame, and exudation of lymph takes place in them, especially at and just above the divided part of the coats constricted and held in contact by the ligature. Thus, as by primary adhesion, or by an adhesive inflammation, the wound made by the ligature in the middle and internal coats is united; and, through the same process, this union is strengthened by the adhesion of these coats to the outer coat, and of the outer coat to the sheath or other immediately adjacent tissues. There is a general adhesion of these parts to one another; they appear thickened, infiltrated, and morbidly adherent: beneficial as the result is, it is the result of disease. Through the same disease, the portion of the outer coat of the artery included within the ligature ulcerates, permitting the removal of the ligature, and a more natural process of organization of the inflammatory products among which it lay, and which its presence had tended to increase.

(2.) When any part of an artery, through any cause, ceases to be traversed by blood, its walls tend to contract and close its canal. The application of a ligature brings

into this condition all that part of the tied artery which lies between it and some branch or branches higher up, through which the stream of blood may be carried-off. The walls of this part therefore slowly contract, gradually reducing the size of its canal, and, in some instances, probably, closing it. There is not in this, as in the last-described part of the process, any disease: the contraction is only the same as that of the ductus arteriosus, the umbilical arteries, and other vessels, from which, in normal life, the streams of blood are diverted; and the closure may, as in them, according to Rokitansky,* be assisted by deposit from the blood thickening with an opaque-white layer the internal coat. The time occupied by this contraction, and its extent in length along the artery, are too various to be stated generally. When it is permanent, the coats of the artery, at its completion, waste, lose their peculiar structures, and are slowly transformed into a fibrous tissue, such as that which composes the solid cord of the ductus arteriosus.

(3.) Respecting these two consequences of the application of ligatures, little difference of opinion can exist; and it may be repeated, that either of these may suffice for the safe closure of the artery. Thus, on the one hand, we sometimes see an artery pervious to the very end of a stump, but there safely closed at the seat of ligature; and, on the other, the naturally torn umbilical arteries of animals, and, I suspect, the arteries which in common wounds are divided and spontaneously cease to bleed, are closed and obliterated without inflammation. However, much more commonly, the blood contained in and near the end of the tied artery becoming stagnant, concurs, with both the processes just described, to the closure of the canal.

* Pathologische Anatomie, B. ii. p. 623.

Concerning this third constituent of the process, more questions have been raised. I shall describe it from the admirable observations of Stilling* and Zwicky.† They were made in large series of experiments on the arteries of animals: those of Stilling refer chiefly to the changes visible to the naked eye, those of Zwicky to the more minute.

When an artery is tied, the blood, as already said, becomes nearly stagnant in the canal, from the ligature upwards to the first principal branch. In an uncertain time, varying from one to eighteen hours, a part of this blood coagulates; and the clot commonly assumes a more or less conical form. The base of this "conical clot," "internal obturator," "plug," or "thrombus," rests in and fills the end of the artery, at the wound made by the ligature; its apex usually lies nearly opposite the first branch above, in the axis of the artery: it is surrounded by fluid, but still nearly stagnant, blood, which, except at its base, intervenes between it and the internal surface of the artery. At its base, and higher up if it fills the artery, the clot is dark and soft, like a common blood-clot: its upper part and apex are denser, harder, and whitish, like coagulated fibrine; and layers of white substance are often gradually superadded to its middle and apex, and increase its adhesion to the walls of the vessel.

In course of time, the clot becomes marked with paler spots, and then porous, spongy, and cavernous, as if it were being gradually channelled from its surface towards its central parts. In this state, injection impelled into the artery will enter and distribute itself in the clot, making it appear

* Die natürl. Prozesse bei der Heilung durchschlungener Blutgefäße. Eisenach, 1834.

† Die Metamorphose des Thrombus. Zurich, 1845.

vascular, or like a cavernous tissue.* While thus changing, also, it becomes gradually more decolorized, passing through ruddy, rosy, and yellowish tints, till it is nearly colourless. As it loses colour it gains firmness, and its base and the greater part of its length become more firmly adherent to the inner surface of the artery, directly or through the medium of the lymph deposited on it. In this increasing firmness, the clot, moreover, is acquiring a more definitely fibrous texture; and, as the same change is gradually ensuing in the inflammatory products deposited near the ligature, the clot and they unite more firmly than before. The walls of the artery, also, gradually closing-in on the clot, unite with it; and, finally, as they also lose their peculiar texture, and become fibrous, the clot and they, together, form the solid fibrous cord by which the tied portion of the artery is replaced; a cord which commonly extends, as did the clot, from the seat of the ligature to the first principal branch above it.

The minuter changes in the clot, associated with those visible to the naked eye, are, chiefly, that it acquires a fibrous or fibro-cellular texture, and becomes vascular. I have already said (p. 173), that Zwicky has traced the development of the fibrine of the clot into fibrous tissue through the formation of nucleated blastema; and, probably, I need not add to the descriptions of this process already drawn from other though similar instances of it (pages 186 and 269). The development, or, at least, the later part of it, is accomplished much more slowly than in

* It was such an injection, probably, that half deceived Hunter into the belief that he had found the beginning formation of new blood-vessels in the clot (*Works*, vol. iii. p. 119; and *Museum of the College*, No. 11); and such led Stilling into one of the few errors in his essay, inducing him to believe that the clot thus became vascular independently of the vessels of the surrounding parts.

the reparative material of tendons in rabbits; needing more than ten weeks in the clots formed in dogs, and more than two years in those in men. The retardation may depend in some measure on the presence of the blood-corpuscles in the clot; for these, though they seem not to affect, or take part in, the development of the fibrine, yet probably, as they suffer degeneration preparatory to removal, may retard it.*

The blood-vessels usually enter the organizing clot, in dogs, in the fourth week, when already it has acquired a nucleated and imperfectly fibrous tissue, and firmness in the place of the spongy texture from which it had derived a spurious appearance of vascularity. They pass into it, apparently, from the vessels formed in the lymph exuded within the artery, in and just above the situation of the ligature; hence they enter its lower part, and gradually extend towards its apex.

Such is the important process for the healing of tied arteries. In applying the description drawn from experiments on animals to the cases of human arteries, the same allowance must be made as in the repairs of fractures and of divided tendons. The process is less speedy, less simple, less straightforward (if I may so speak), more prone to deviate and to fail, through excess of that disease, by a measured amount of which the security of the artery is achieved.†

* The changes ensuing in the blood-corpuscles are described by Zwicky; but I omit them, since they take no evident part in the reparative process, and are, as yet, not clearly ascertained.

† Rokitansky (B. ii. p. 616) may be referred to concerning some events in the process which are not yet clearly ascertained; such as the amount to which, in some cases, the clot may be absorbed, and the share taken by deposit from the blood producing opaque-white thickening of the inner coat of the artery.

The *Healing of Divided Nerves* may be accomplished in two methods, which may be named, respectively, primary and secondary union, and may, probably, be compared with the processes of primary adhesion (p. 198), and of connection by intermediate new-formed bonds (p. 267).

I know no instances in which nerves healed in the first method have been examined, but the nature of the process may be explained by the history of a case in which it occurred:—

A boy, eleven years old, was admitted into Saint Bartholomew's Hospital, under Mr. Stanley, with a wound across the wrist. This wound, which had been just previously made with a circular saw, extended from one margin to the other of the fore-arm, about an inch above the wrist-joint. It went through all the flexor tendons of the fingers and thumb, dividing the radial artery and nerve, the median nerve and artery, and extending for a short distance into the radius itself. The ulnar nerve and artery were not injured; the condition of the interosseous artery was uncertain, but the interosseous ligament was exposed at the bottom of the wound. Half an inch of the upper portion of the divided median nerve lay exposed in the wound, and was distinctly observed and touched by Mr. Stanley, myself, and others. All sensation in the parts supplied from the radial and median nerves below the wound was completely lost directly, and for some days after the injury.

The radial artery was tied, and the edges of the wounded integuments put together. No particular pains were taken to hold the ends of the divided median nerve in contact, but the arm was kept at rest with the wrist bent.

After ten days or a fortnight the boy began to observe signs of returning sensation in the parts supplied by the median nerve, and these increasing, I found, a month after the wound, that the nerve had nearly recovered its con-

ducting power. When he was blindfolded, he could distinctly discern the contact of the point of a pencil with his second finger, and the radial side of his third finger; he was less sure when his thumb or his fore-finger was touched, for, though generally right, he sometimes thought one of these was touched when the contact was with the other; and there were a few and distant small portions of the skin supplied by the median nerve from which he still derived no sensation at all.

Now all this proves that the ends of the divided median nerve had coalesced by immediate union, or by primary adhesion with an exceedingly small amount of new substance formed between them. In the ordinary secondary healing of divided human nerves, twelve months generally elapse before, if ever, any restoration of the function is observed; in this case, the nerve could conduct in a fortnight, and perhaps much less, after the wound. The imperfection of its recovery is just what one might expect in such a mode of union. One might anticipate that some of the fibres in one of its portions would fail to be united to any in the other portion: and the parts supplied by these filaments would necessarily remain insensible. So, again, one might expect that some of the fibres in one portion would unite with some in the other, with which they were not before continuous, and which supplied parts alien from those to which themselves were destined: in all such dislocations of filaments there would be confused or transferred sensations. But, among all the fibres, some would again combine in the same continuity in which they had naturally existed: and in these cases the function would be at once fully restored.*

* I saw this boy again nearly a year after the injury. He had almost perfect sensation in all the distribution of the median nerve, except in the last phalanges of the thumb and fore-finger. These had

While this case was under observation, Mr. Gatty sent me, with the permission of Mr. Heygate, in whose practice the case occurred, the following particulars of a similar instance of repair.

A lad, near Market Harborough, thirteen years old, had his hand nearly cut off at the wrist-joint by the knife of a chaff-cutting machine. The knife passed through the joint, separating a small portion of the ends of the radius and of the ulna, and leaving the hand attached to the fore-arm by only a portion of integument about an inch wide, connected with which were the ulnar vessels and nerve, and the flexor carpi ulnaris muscle—all uninjured. The radial artery and some small branches being tied, the hand and arm were brought into apposition, and after removing a small portion of extensor tendon that protruded, were retained firmly with adhesive plaister and a splint of paste-board. The wound went on very well, and was left undisturbed for a week. The warmth of the hand returned; in ten or twelve days after the injury there was slight sensation in the fingers, but in the thumb none was discernible till more than a fortnight had elapsed. Finally, the sensation of the hand and fingers, and most of their movements, were perfectly restored.

In this case, again, it seems impossible to explain the speedy restoration of the conducting power of the nerve, except on the supposition that its divided fibres had immediately reunited. We have no evidence that new nerve-

not decreased or changed in texture; but they were very liable to become cold, and he came to the hospital because large blisters had formed on them. He had been warming his hands at an open fire, and the heat, which was not uncomfortable to the rest of the hands, had blistered these parts, as boiling water would have blistered healthy ones. He had almost completely recovered the movement of his fingers.

fibres could in so short a time be formed: all the cases of less favourable healing show that they require a year or more for their formation.

I need hardly add the practical rule we may draw from these cases. It is, briefly, that we may, with good hope of great advantage, always endeavour to bring into contact, and immediately unite, the ends of divided nerves; and that we need not in all such cases anticipate a long-continued suspension of the sensation and other functions of the part the nerves supplied.

The secondary healing of divided nerves presents many features similar to that of divided tendons. A bond of new substance is formed, which connects the ends of the retracted portions of the nerve, and in which, though at first it is like common reparative material, new nerve-fibres form, and connect themselves with the fibres in the portions above and below. I need not dwell on the formation or development of this connecting bond: the subject is amply treated in several works on physiology;* and it is thoroughly illustrated, so far as the appearances to the naked eye are concerned, by the valuable series of preparations given to the Museum of the College by Mr. Swan.† But the observations of Dr. Waller‡ have added some remarkable facts to those hitherto ascertained. Watching the process that follows the division of the glosso-pharyngeal nerve in frogs,

* See especially Müller's Physiology, by Baly, i. 457; Valentin's Physiologie, i. 702; Hildebrandt's Anatomie, i. p. 291.

† Nos. 2169 to 2175. All these specimens, and the appearances of the formation of new nerve-fibres which they display, are described and illustrated by Mr. Swan, in his "Treatise on the Diseases and Injuries of Nerves." In Nos. 2165 to 2168 in the College Museum, Mr. Hunter has shown the formation of the bulb at the ends of divided nerves, and the extension of nerve-fibres into it.

‡ London Journal of Medicine, July 1852.

he has found that after a nerve is divided, the old fibres, in the distal portion, never recover their functions. They degenerate, and new fibres are gradually formed in the whole length of the nerve, from the place of division to the peripheral distribution. These new fibres connect themselves with those in the connecting bond of repair, and through these with the old fibres in the proximal portion of the nerve. They are, and permanently remain, like the nerve-fibres of the embryo: they lie between the shrivelled older fibres; and are not formed unless union have first taken place between the divided parts of the nerve.

The repair of nervous centres has been comparatively little studied. The experiments of M. Brown-Sequard* have proved that, after complete division of the mid-dorsal part of the spinal cord of pigeons, and after division of more than half of that of guinea-pigs, the sensibility and movements of the hinder part of the body may be almost completely restored in about twelve months; and that the substance by which the injury of the cord is healed contains, with fibro-cellular tissue, abundant well-formed nerve-fibres connected with those of the cord above and below, and sparing nerve-cells.

Schrader's experiments of dividing and removing small portions of the cervical ganglia, and the ganglion of the vagus, of rabbits, found union by fibrous bonds, but no regeneration of ganglion-cells after eleven weeks.† Valentin's similar experiments had scarcely a more positive result.‡

After wounds and losses of substance of the brain, a

* Comptes Rendus de la Soc. de Biologie, t. i. p. 17; t. ii. p. 3; t. iii. p. 77.

† Experimenta circa Regenerationem in Gangliis nervis. Göttingen, 1850.

‡ Physiologie, i. 708.

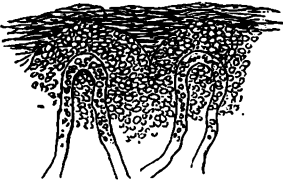
large quantity of new material may be formed to fill up the gap;* but observations are wanting to show how much this may contain of proper cerebral substance. I have found nerve-fibres in it after thirty-three years (see p. 83); but in the same specimen there was no appearance of grey matter.

The last tissue to the healing of which I shall particularly refer, is the skin. I need not indeed describe the whole process, because nearly all that was said of the healing processes generally was chiefly illustrated by instances of wounds involving the skin. Yet it may be useful to indicate the skin as, on the whole, the part which, being most exposed to injury, is capable of the best repair; that which heals most commonly by the immediate union, most quickly by primary adhesion; that which produces the most rapidly and securely organizing granulations. The healing of skin is further favoured by its extensibility and loose connection with adjacent parts; so that, when large surfaces are to be healed, the contracting granulations can draw over their borders the loose skin around. Moreover, the new-formed skin imitates the old skin very well, if we consider the complexity of its structure. I am not aware that the smooth muscular fibres, or any of the glandular structures of the skin, are formed in its scars; but its fibro-cellular and elastic tissues, its papillæ and epidermis, are all well-formed in them. It is commonly said that the smoothness of a scar is due to the absence of papillæ, but I believe it depends only on the tightness of the new-formed skin, and its want of such wrinkled and furrowed lines as naturally exist. If a thin section be made of the border of a healing

* See especially Arnemann: *Versuche über das Gehirn und Rückenmark*. Göttingen, 1787.

wound, so as to include the new-formed layer of epidermis, the granulations now skinned-over will be found, as in the

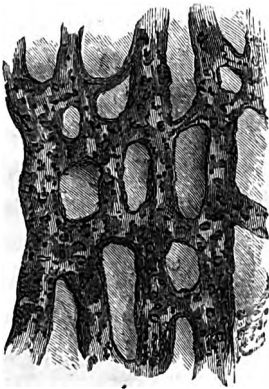
FIG. 26.



annexed diagram (fig. 26, A), presenting the papillary form. They consist still of nucleated cells, but the shape of papillæ is acquired, or, rather, is retained; for the likeness of a granulating surface to a finely papillary one is evident, and may be regarded as an ex-

ample of the general tendency of new-formed structures, even in disease, to assume a plan of construction similar to that of the adjacent parts. The likeness extends to the arrangement of the blood-vessels; and the papillary struc-

FIG. 27.



ture is not lost in the later development of the scar. If the epidermis of a scar be separated, its under surface will present a series of depressions corresponding with the elevations of the papillæ on which it was adapted. The adjoining sketch represents the under surface of epidermis so reflected from a scar on the arm of a negro: and may illustrate not only the plan of the papillæ, of which it was like a mould,

but, by its colour, the complete reproduction of a rete nigrum.*

* For the further study of the healing process, especially in the tissues and organs not mentioned in this lecture, I must refer the reader either to special treatises on the pathology of those parts, or to the chief works on General Anatomy, especially, in relation to all

In concluding the lectures on Repair, and before beginning those on Inflammation, let me briefly state the relations of the one process to the other.

It is not because we have any well-defined idea of inflammation that it is desirable to refer to it, as if it were a standard with which we might compare other organic processes; but such a reference seems necessary, because some idea of inflammation mingles itself with nearly everything that is considered in surgical pathology. Nowhere is this more manifest than in what has been written in surgical works upon the methods of repair; concerning which a general impression seems still to be, that a process of inflammation forms part of the organic acts by which even the smallest instance of repair is accomplished.

Now the processes we have traced appear to warrant these general conclusions:—

1. In the healing of a wound by immediate union, inflammation forms no necessary part of the process; rather, that its presence always hinders, and may completely prevent it. The healing by immediate union should be a simple re-joining of the severed parts, without the production of any new material; and in the same proportion as, in any case, inflammatory matter is effused, either in or between the wounded parts, in that proportion does the

but microscopic observations, to that of Hildebrandt, edited by E. H. Weber; and to the chapters on Reproduction in Müller's *Physiology*, by Baly, vol. i. p. 440, and in Valentin's *Physiologie*, i. 700. The power of repair in the cornea is illustrated especially by Dr. Bigger, in the *Dublin Journal of Med. Science*, 1837; and by Donders, in the *Onderzoekingen. . . der Utrechtsche Hoogeschool*, D. i. p. 31.—The repair of fractured teeth by bone is described by Mr. Tomes in his "Dental Surgery." The Museum of the College has the best specimens illustrating repair, that I am acquainted with.

healing deviate from the true and best process of immediate union.

2. For subcutaneous wounds and injuries, as in divided tendons, simple fractures, and the like, nearly the same may be said. Inflammation is excited by the local injury, but its products form no necessary part of the material of repair; rather, the more abundant they are, the more acute the inflammation is, and the longer it continues, the less speedy and the less perfect is the process of repair. For here the necessary or best reparative material is a substance which is produced without the signs of co-existent inflammation, and of which the development is different from that of the inflammatory products that are mingled with it. And this, which is most evident in the case of the healing of subcutaneous injuries by bonds of connection, is probably equally true in the case of subcutaneous granulations.

3. In the healing of a wound by primary adhesion, or by open granulations, we, usually, have evidence of a process of inflammation, in the first instance, in the presence of its ordinary signs, in a degree generally proportioned to the severity and extent of the injury.

4. Still, in these cases, the signs of an inflammatory process are often absent; and even when they exist, the process appears necessary for no more than the production of the organizable matter, and, in the case of granulations, for the production of only the first portions of it. The right formation of the cells, and, yet more evidently, their higher organization into cellular and other tissues, ensue only while the signs of inflammation are absent. They are manifestly hindered or prevented when signs of inflammation are present, or when its existence may be suspected in consequence of the presence of some irritation, as a foreign body, dead bone, or the like. The continuance

of suppuration, also, during the process of healing, is no proof of the continuance of inflammation, if the account that I have given of pus be true.

In these two modes of healing, therefore, we may conclude that inflammation is sometimes absent, and is, in any case, only partially, and at one period, requisite ; and that, in regard to its requisite degree, the least amount with which an exudation of lymph is possible, is that which is most favourable to repair.

5. For the process of healing by scabbing, the absence of inflammation appears to be essential : indeed, the liability of our own tissues to the inflammatory process, and to the continued exudation that it produces, appears to be that which prevents their injuries from being healed as easily and surely, by the scabbing process, as nearly all open wounds are in animals.

Lastly, in certain cases, the artificial production of an inflammatory process is necessary for repairs for which the natural processes are insufficient or insecure. Among these, are the cases of fractures remaining disunited, and of arteries and veins needing ligatures.

Such may be regarded as the relations of the reparative process to that of inflammation, as it is commonly understood ; but, I repeat, such a comparison can be made only for the sake of deference to the general state of opinion in matters of surgical pathology. In truth, we know less of inflammation than of the reparative process.

LECTURE XIII.

PHENOMENA OF INFLAMMATION.

It is no more than the truth which Mr. Travers has well expressed in his work on the "Physiology of Inflammation and the Healing Process"—"that a knowledge of the phenomena of inflammation, the laws by which it is governed in its course, and the relations which its several processes bear to each other, is the key-stone to medical and surgical science."

I shall not attempt to define inflammation in any set terms; for as yet we are not, I think, in a position to do this. Just definitions cannot be made in any science till some of its broad and very sure principles have been established. Such principles we cannot boast to have yet attained in the study of pathology; and the attempts at precise definitions that have been made hitherto, seem to have led to confusion, or to false and narrow views of truth. Besides, to define inflammation is the less necessary, because, practically, we all know sufficiently well what the term implies: we know the signs of the presence of the disease in all its chief forms; and, when we watch these signs in any external part, we see them so often followed by peculiar changes in the part, that we are justified in recognizing the changes as effects of inflammation, and in believing that wherever we find them, the similar or corresponding signs of inflammation have preceded them.

But the very difficulty of exactly defining the process of inflammation may be our guide to the most hopeful method of investigating it. When we see such gradual transitions from the normal process of nutrition to the disease of inflammation, that we cannot draw a definition-line between them, we may be sure that the main laws of physiology are the laws alike of the disease and of the healthy process ; that the same forces are engaged in both ; and that, though interfered with by the conditions of the disease, they are not supplanted or annulled.

Now, such transitions from the normal processes to that of inflammation are not rare. We may trace them, for example, in the gradual passage from the active exercise of the brain, or of the retina, to its "irritation" when over-worked, and thence to its complete inflammation and impairment of structure, after long exposure to what had been a natural stimulus, or to what, in a less degree, might be so. Or, on the introduction of medicines, such as certain diuretics, into the blood, we may trace gradations from the normal increase of the functions of the kidneys, under what is regarded as no morbid stimulus, to their intensest inflammations. Or, again, in the application of an abnormal stimulus, such as that of a heat greater than the natural temperature of the body, where shall we mark the line at which inflammation begins to supervene on health? We may, indeed, say that stagnation of blood, or effusion of liquor sanguinis, or some exudation, or some degenerative change in the elements of the affected tissue, shall be the condition *sine quâ non* of inflammation ; we may call whatever falls short of these, "active congestion," "irritation," or by any other name ; but, in reality, such distinctions are often impossible, and sometimes untrue, and in study, the terms are convenient for the sake of brevity rather than of clearness.

Evading, then, the question of the precise definition of inflammation, I shall endeavour, first, to describe the state of an inflamed part, giving to the description such a plan and direction as may best help the chief design—first, of contrasting the inflammatory with the normal method of nutrition ; and, secondly, of showing that the immediate causes, and the chief constituents, of the inflammatory state are to be found in alterations of those things which are necessary conditions of the healthy nutrition of a part. It will be easy to connect with such a description the explanations, so far as they can be given, of the constituent signs or phenomena of inflammation,—the redness, swelling, heat and pain, and the disturbed function of the part.

The conditions of the healthy maintenance of any part by nutrition, are, as illustrated in former lectures (p. 15)—1st, a regular and not far distant supply of blood ; 2d, a right state and composition of that blood ; 3d (at least in most cases), a certain influence of the nervous force ; and 4th, a natural state of the part in which nutrition is to be effected. All these are usually altered in inflammation.

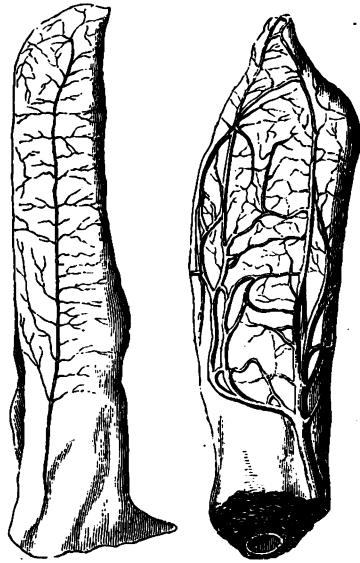
I. The supply of blood to an inflamed part is altered, both by the changes of the blood-vessels, especially by their enlargement, and by the mode in which the blood moves through them.

The enlargement of the blood-vessels is, I suppose, a constant event in the inflammation of a part ; for, although in certain parts, as the cornea, the vitreous humour, and the articular cartilages, some of the signs or effects of inflammation may be found where there are naturally no blood-vessels, yet I doubt whether these ever occur without enlargement of the vessels of the adjacent parts, and especially of those vessels from which the diseased structure

derives its natural supply of nutritive material, and which may therefore be regarded as its blood-vessels, not less than those of the part in which they lie. Thus, in inflammation of the cornea, the vessels of the sclerotica and conjunctiva are enlarged, and in ulceration of articular cartilages those of the surrounding synovial membrane or subjacent bone.

The enlargement usually affects alike the arteries, the capillaries, and the veins of the inflamed part; and usually extends to some distance beyond the chief seat or focus of the inflammation. To it we may ascribe the most constant visible sign of inflammation, the redness, as well as much of the swelling. Its amount is various; it may be hardly perceptible, or it may increase the vessels to two or three times their natural diameter. Extreme enlargement is admirably shown in Hunter's specimen* of the two ears of a rabbit, of which one was inflamed by thawing it after it had been frozen. "The rabbit was killed when the ear was in the height of inflammation, and, the head being injected, the two ears were removed and dried." A comparison of the ears, or of the drawings from them (Fig. 28), shows all the arteries of the inflamed

FIG. 28.



* Museum of the College, No. 71. See, also, Hunter's Works, vol. iii. p. 323, and pl. xx.

ear three or four times larger than those of the healthy one, and many arteries that in the healthy state are not visible, are, in the inflamed state, brought clearly into view by being filled with blood.

I have repeatedly seen similar enlargements of both arteries, and veins, and capillaries, in the stimulated wings and ears of bats. The like phenomena occur in the webs of frogs, and other cold-blooded animals ; but in these, I think, the amount of enlargement is generally less.*

The redness of an inflamed part always appears more than is proportionate to the enlargement of its blood-vessels ; chiefly, because the red corpuscles are much more closely crowded than they naturally are in the blood-vessels. The vessels of an inflamed part are not only dilated, but appear crammed with the red corpuscles, which often lie or move as if no fluid intervened between them : their quantity is increased in far greater proportion than that of the liquid part of the blood.

This peculiarity is even more manifest in the frog than in the bat ; for in the former, the crowding of corpuscles may occur in vessels that appear to have undergone no change of size on the application of the stimulus.†

Another, but a minor, cause of the increased redness

* Emmert, who is among the few that have measured it, says it is equal to one-half or one-third of the normal diameter of the vessels. Lebert says one-sixth to one-third (*Gazette Médicale*, Mai 15, 1852).

† I do not more particularly refer to what is described as the encroachment of the red blood-corpuscles on the lymph-space, or the layer of fluid that lies in apparent rest adhering to the walls of the vessels. The too pointed description of this layer has led to exaggerated notions concerning it. Its existence is certain, but it is too thin for any blood-corpuscle to lie at rest in ; and when white corpuscles remain by the walls of the vessels, it is evident that they do so more because of their own adhesiveness than because a small portion of the fluid about them is at rest.

of the inflamed part, is sometimes to be observed in the oozing of the colouring matter of the blood-corpuscles, both into all the interspaces between them, and through the walls of the small vessels into the adjacent tissue. During life this may be noticed, especially when the blood is stagnant in the vessels, and it may give them a hazy, ruddy outline; but it is generally much more considerable after death, when we may ascribe to it no small portion of the redness that an inflamed part may still present.

In the state of inflammation no new blood-vessels are formed. Many more may come into view than were at first seen in the part; but these are only such as were invisible till the flood of blood-corpuscles filled and distended them. So it was in the rabbit's ears; in the healthy ear no trace can be seen, with the naked eye, of any vessels corresponding with one of the largest, or with many of those of inferior size, in the inflamed ear. So it is, too, in microscopic examinations. Within half an hour after stimulating a bat's wing, many vessels may come into view which could not be seen before with the same lens, and with which none can be seen corresponding in the other wing, though doubtless such vessels exist there of smaller size.

It is only when the inflammation has subsided, and the lymph exuded from the blood-vessels begins to be more highly organized, that new vessels are formed, and pass into the lymph, as if for the maintenance of its increase or development.* So long as the inflammation lasts, the intensest redness in parts naturally colourless,—even such as we see in acute inflammations of the conjunctiva, or yet more remarkably in those of periosteum,†

* Mr. Hunter held this opinion; but more lately the contrary one has been commonly held. See his Works, vol. iii. p. 322.

† As illustrated in Mr. Stanley's plates; plate vii. fig. 1, which represents a specimen in the Museum of St. Bartholomew's, Series i.

or in congestion of the stomach,—is due to the enlargement of the natural blood-vessels, to their admitting crowded red corpuscles, and in a much less degree, and, perhaps, in only certain cases, to the diffusion of the colouring matter of the blood.

With the enlargement of the blood-vessels a change of shape is commonly associated. Being usually elongated as well as dilated, they are thrown into curves and made more or less wavy or tortuous. Thus we may see the larger vessels in an inflamed conjunctiva, and, more plainly, the subperitoneal arteries in cases of peritonitis; so, too, they are represented in the inflamed rabbit's ear.

A more remarkable change of shape of the small vessels of inflamed parts is that in which they become aneurismal or varicose. The first observations of this state were published, I believe, by Kölliker and Hasse, in an account of a case of inflammatory red softening of the brain, in which many of what, at first sight, appeared to be points of extravasated blood, proved to be dilatations of capillary vessels filled with blood. After this they found the same changes, but in a much less degree, in some cases of inflammation artificially excited in the brains of rabbits and pigeons.* Many, as well as myself, have since made similar observations, most of which, however, seem to show that the peculiar dilatation has its seat in the small arteries and veins, as well as in the capillaries of the inflamed part.

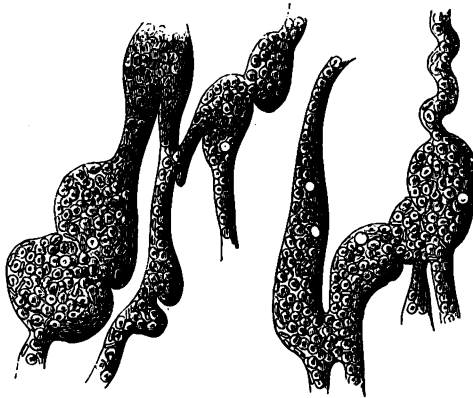
Among the various forms of partial dilatation, some are like gradual fusiform dilatations of the whole circumference

No. 195. The whole inner surface of the inflamed periosteum of a tibia is bright scarlet.

* *Zeitschr. für wissensch. Zoologie*, B. i. p. 262. Mr. Kiernan had observed the same changes some years previously. See Dr. Williams's *Principles of Medicine*, 2d edit. p. 287.

of the vessel ; some like shorter and nearly spherical dilatations of it ; some like round, or oval, or elongated pouches, dilated from one side of the wall : in short, all the varieties of form which we have long recognised in the aneurisms and aneurismal dilatations of the great arteries may be found in miniature in the small vessels of such inflamed parts. Some of these forms are represented in fig. 29, from the small vessels of an inflamed pericardium.

FIG 29.



Frequently, however, as this state of the small vessels has been observed in inflamed parts (and I believe some measure of it may be found in the inflammations of most membranes),* yet, I think, we may not assume it to have a necessary or important connection with the other phenomena of inflammation. It is often observed, as Virchow† especially has shown, in other, besides inflammatory, diseases ; and, in all alike, may be referred to a gradual

* Lebert says it is a constant occurrence in experimental inflammations of the subcutaneous tissue of frogs. *Gazette Médicale*, Mai 22, 1852.

† In his *Archiv*, B. iii. p. 432.

deterioration of the structure of the vessels, weakening them, and rendering them unable to resist uniformly the increased pressure of the blood. Perhaps, in some cases, as Mr. Quekett has suggested to me, the pouch-like dilatations may represent a disturbed effort for the production of new blood-vessels by dilatation, or outgrowth of the walls of those already extant.

Such is the ordinary state of the blood-vessels of an inflamed part : all dilated and elongated, tensely filled with blood, of which the red corpuscles are in excess, often wavy and tortuous, and sometimes variously aneurismal.

But the supply of blood to an inflamed part is affected by its mode of movement, as well as by the size of the blood-vessels : this, therefore, I must now describe.

Nearly all the observations hitherto recorded, on the morbid changes in the movement of the blood, have been made with the webs of frogs ; and it has been objected that it is not safe to apply conclusions drawn from them to the case of warm-blooded animals. I have therefore employed the wings of bats, in which (when one has acquired some art in quieting them with chloroform or gentle management) nearly all the phenomena of the circulation, as affected by the application of stimuli, may be watched as deliberately as in the frog, and in some respects even more clearly.

I think we may believe that what may be seen in the wings of bats occurs, in the like circumstances, in all warm-blooded animals. It is true that, like the other hybernants, the bats, while they are in their winter-sleep, resemble the cold-blooded animals, in that their temperature is conformed to that of the external air, and scarcely exceeds it. It is true, also, that when they are ill nourished, their temperature, even in their active state, is comparatively low, ranging from 65° to 80° F., in an atmosphere of 60° ; and

that generally they are liable to much greater diversities of temperature than our own bodies are.* And the remarkable condition, discovered by Mr. Wharton Jones,† that those veins in the wing that have valves contract with regular rhythm for the acceleration of the venous stream, may affect in some measure the morbid as well as the normal movement of the blood. Still, since in the development of their nervous system, and the commensurate development of their heart and respiratory organs, and in the close reciprocal relations in which these act, the bats resemble the other warm-blooded vertebrata, we may, I think, fairly assume a close resemblance also in their processes and conditions of nutrition.

* For instance, I found the temperature of a strong and active Noctule-Bat (*Vespertilio Noctula*) thus various in two days :—

April 29th, at noon, after he had been nearly two hours under the influence of chloroform, and on awaking had been struggling very actively, his temperature was 99° F. At 9 P.M., having meantime been quiet, hanging by his hind feet, and looking sickly, his temperature was only 70°. When disturbed he became very fierce and active, shrieking and biting the bars of his cage; and at 9h. 40m. his temperature was 92°. Soon after this he became quiet again, and at 10h. 30m. his temperature was 80°. The temperature of the atmosphere during these examinations had gradually increased from 61° to 67°.—April 30th, at 8 A.M., he was feeble, but not torpid: the temperature of the room during the night had been between 40° and 45°, and was now 57°; the temperature of the bat was only 59°. At 11 A.M., after struggling violently for half an hour, it rose to 69°. After being long under chloroform, and nearly dying, he remained all the afternoon only one or two degrees warmer than the atmosphere. But at night, at 12h. 15m., he recovered and became active; and, while the atmosphere was at 65°, he was at 85°. At 12h. 40m., after being made very fierce, he was at 88°; and at 1h. 30m. remained at 85°. Next morning he was again scarcely warmer than the atmosphere. The temperature was always taken with a small thermometer applied to the surface of the abdomen.

† Philos. Trans., 1852, Part 1.

The simplest effects upon the blood-vessels are produced by a slight mechanical stimulus. If, as one is watching the movement of blood in a companion artery and vein, the point of a fine needle be drawn across them three or four times, without apparently injuring them or the membrane over them, they will both presently gradually contract and close. Then, after holding themselves in the contracted state for a few minutes, they will begin again to open, and, gradually dilating, will acquire a larger size than they had before the stimulus was applied.*

Simple as this observation is, it involves some cardinal facts in our pathology. It illustrates, first, the contractile power of both arteries and veins ; it shows that this is possessed by the smallest, just as it is by the larger, vessels of both kinds ; and, by the manner of their contraction, which follows at some interval after the application of the stimulus, and is slowly accomplished, it shows that their power of contraction is like that of parts with smooth or organic muscular fibres.

But, again, the experiment shows the vessels reopening

* Some doubt must exist as to the contraction of the veins here described ; for Mr. Wharton Jones has not been able to convince himself of it. He considers, also, that in the frog's web the veins are capable of but slight variation in diameter through the operation of contractile power ; and this accords with E. H. Weber's observations (Müller's Archiv, 1847). Lebert, on the other hand, expressly says that he has observed the same various states of contraction in the veins as in the arteries of the frog's web. In most other points relative to the condition of the blood-vessels, and the movement of the blood in them, my observations accord with those which Mr. Wharton Jones had completed, but not published, when the lectures were delivered. The reader may, however, find in his admirable essay (Guy's Hospital Reports, 1850) many minute details which I had not learned, and many illustrations of singular beauty and accuracy. I cannot doubt that his later researches with the bat's wing will much improve the description I have given.

and becoming wider than they were before ; either yielding more to the pressure of the blood which previously they resisted with more strength, or else dilating, as of their own force, with that which Mr. Hunter called active dilatation, and compared with the act of dilatation of the os uteri. In whichever way the dilatation is effected, whether it be active or passive, the vessels will not at once contract again under the same stimulus as before affected them. The needle may be now drawn across them much oftener and more forcibly, but no contraction ensues, or only a trivial one, which is quickly succeeded by dilatation. Yet with a stronger stimulus, such as that of great heat, they will again contract and close. And such a contraction excited by a cautery may last more than a day, before the vessels again open and permit the flow of the blood through them.

Moreover, we may observe in this experiment the adapted movement of the blood. As the vessels are contracting the blood flows in them more slowly, or begins to oscillate ; nay, sometimes, I think, even before the vessels begin visibly to contract, one may observe that the blood moves more slowly in them, as if this were an earlier effect of the stimulus : nor have I ever seen (what has been commonly described) the acceleration of the flow of blood in the contracting vessels. Such an acceleration, however, is manifest, as the vessels reopen ; and as they dilate, so, apparently in the same proportion, does the flow of blood through them become more free, till, at length, it is manifest that they are traversed by both fuller and more rapid streams than passed through them before the stimulus was applied. How long this state may last depends on many circumstances hard to estimate : but at length it ceases, and the vessels, and the circulation through them, assume again their average or normal state.

Such are the effects of the mechanical stimulus of blood-vessels.

The effects of other stimuli applied to the wings of bats correspond in kind, but differ in degree and extent. If a drop of acetic acid, of tincture of capsicum, of turpentine, or of ethereal solution of cantharides, be placed on a portion of the wing, or washed over it, one sees a quickly ensuing dilatation of the blood-vessels, and a rapid flow of blood through them all. I am not sure that the dilatation is preceded by contraction. Certainly the contraction is very slight, if it occur at all ; but the dilatation is usually much more extensive. When the stimulus has been applied to only one small spot upon the wing, the whole of the blood-vessels in the corresponding metacarpal space, and even those of the adjacent spaces, may enlarge. One might imagine that the dilatation of vessels was due to an increased action of the heart, if it were not that (as I think) it is always greater at the very point to which the stimulus was applied than in any other part of the same wing, and is never at all imitated in the corresponding parts of the opposite wing.

The state which is thus induced by stimuli is what is commonly understood by the expressions "active congestion," or "determination of blood," in a part. It consists, briefly, in general enlargement of the blood-vessels of the part, with an increased velocity of the blood in them. It is, probably, just such a state as this that is felt by suckling women in what they term the "flow of milk." It seems to be an increased flow of blood in the mammary gland just before a quicker secretion of the milk. Less normally, it is such a state as this that we observe in the skin after the application of mustard, or sharp friction, or a heat from 20° to 50° above its own, or, in the most striking instance, when a drop of strongest nitric acid

is placed on the skin, and, in a few seconds, all the surrounding area seems to flush, and feels burning hot. Such, too, we may suppose to be the state of the vessels of the conjunctiva, when stimulated by dust that is soon dislodged; and such the condition of many internal organs, when we might doubt whether they are inflamed, or are only very actively discharging their natural functions. Herein, indeed, in what I have described, is one of the pieces of neutral ground between health and disease: a step in one direction may effect the return to health; in another, the transit to what all might admit to be the disease of inflammation.

Now this transit appears to be made when the circulation, which was rapid, begins to grow slower, without any diminution, but it may be with an increase, of the size of the vessels. This change one may see in the bat's wing. After the application of such stimuli as I have already mentioned, the movement of the blood may become gradually slower, till, in some vessels, it is completely stagnant. The stagnation commences, according to Mr. Wharton Jones, in the capillaries; and first in those which are least in the direct course from the artery to the vein [in the stimulated frog's web]: thence it extends to the veins and to the arteries.

A corresponding state of retardation of blood, leading to partial stagnation of it, may be well seen after such an injury as that of a fine red-hot needle driven into or through the membrane of the wing.

The first effect of such an injury (in addition to the charring and searing of the membrane, the obliteration of its blood-vessels, and the puckering of the portion of it adjacent to the burn) is to produce contraction of the immediately adjacent arteries and veins. They may remain closed, or, as I have already described, after being long closed, may again open, and become wider than they were

before. This dilatation follows more certainly, and perhaps without any previous contraction, in the arteries and veins at a little distance from the burn. In these, there speedily ensues such a state of "determination of blood" as I have already described : in arteries and veins alike the stream is full and rapid ; and the greater accumulation, as well as the closer crowding, of the red corpuscles, makes the vessels appear very deep-coloured. The contrast of two diagrams, showing the natural and the stimulated conditions in a single segment of the vascular plan of the wing, illustrates this difference sufficiently well * (Figs. 30 & 31). The vessels of the one, nearly twice as large as those of the other, darker, and more turgid with blood ; and, in the one, numerous capillaries which are not visible in the other. But diagrams cannot show the changes in the mode of movement. Close by the burn, the blood which has been flowing rapidly begins to move more slowly, or with an uncertain stream ; stopping, or sometimes ebbing, and then again flowing on, but, on the whole, becoming gradually slower. Thus it may, at length, become completely stagnant ; and then, in the vessels in which it is at rest, it seems to diffuse and change its colour, so that its crowded corpuscles give the vessels a brilliant carmine appearance, by which, just as well as by the stillness of the blood, they may always be distinguished. As one surveys an area surrounding this part, one sees streams the more rapid the more distant they are from the focus of the inflammation. And often, when there is stagnation in a considerable artery, one may see the blood above or behind it pulsating with every action of the heart, driven up to the seat of stagnation, and thence carried off by the collateral branches ; while, in the corresponding vein, it may oscillate less regularly, delaying till an accumulated force

* The plan of vessels drawn is copied from Mr. Wharton Jones's plate. Philos. Trans. 1852, Part I.

propels it forward, and, as it were, flushes the channel.* In the area still more distant, one sees the full and rapid and

FIG. 30.

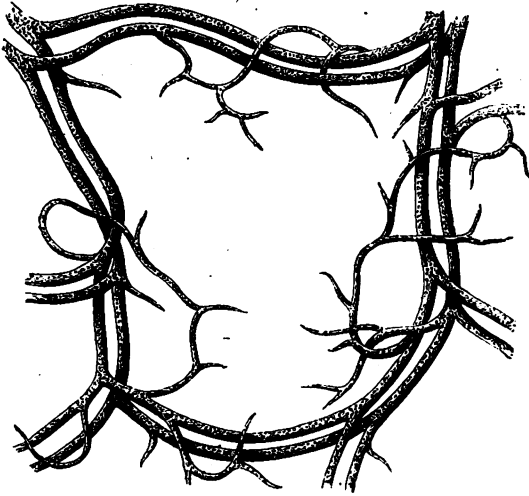
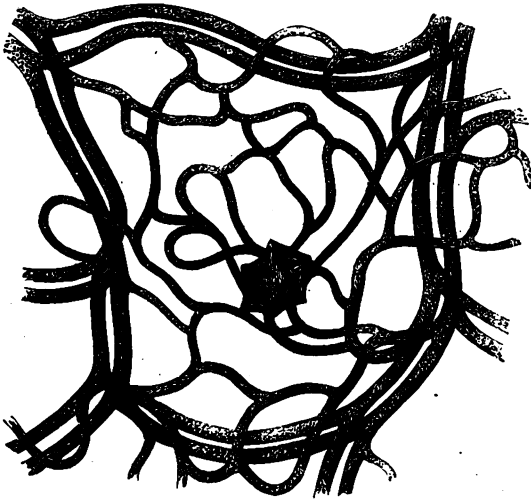


FIG. 31.



* What I thus described was, no doubt, the result of the rhythmical contraction of the veins, which Mr. Wharton Jones has since discovered.

more numerous streams of "determination" or "active congestion," which extend over a space altogether uncertain.

Such is the general condition of the circulation in and around a part that is inflamed. In few words, there is, in the focus of severe inflammation, more or less of *stagnation* of blood ; in and close around it, there is *congestion*,—*i. e.* fulness and slow movement of blood ; more distantly around there is *determination*,—*i. e.* fulness and rapid movement of blood. The varieties in lesser points that may be presented cannot be described. These must be seen ; and, indeed, the whole sight should be viewed, by every one who would have in his mind's eye a distinct image of what, in practice, he must often too obscurely contemplate.

The phenomena that I have described as seen in the bat's wing correspond very closely with those observed in the frog's web. Only I think the stagnation of blood is neither so constant nor so extensive in the bat : it is seen in portions of single vessels, rather than in districts of vessels ; often in corresponding portions of arteries and veins, as they lie side by side. The stagnation usually extends into such branches as may be given from the vessels that are its principal seats ; and three or four such seats of stagnation may appear placed irregularly about the burn, or other focus of the inflammation ; but I have never seen a general stagnation of blood in all the vessels of even a severely stimulated part. My impression is, that, in strong and active warm-blooded animals, stagnation of blood would be found in only the most severely inflamed parts : in others, I think, retardation alone would exist.*

To sum up now what concerns the supply of blood in an inflamed part. We seem to have sufficient evidence that, in general, in the focus of the inflammation, blood is present in very large quantity, distending all the vessels, gorging

* M. Lebert expresses the same belief : *Gazette Médicale*, Mai 22, 1852.

them especially with red corpuscles, but often moving through them slowly, or even being in some of them quite stagnant ; that all around this focus, the vessels are as full, or nearly as full, as they are in it, but the blood moves in them with a quicker stream, or may pulsate in the arteries, and oscillate in the veins ; that, yet further from the focus, the blood moves rapidly through full but less turgid vessels. And this rapidity and fulness are not to be ascribed, I think, merely to the blood, which should have gone through the inflamed part, being driven through collateral channels, but are such a state as is commonly understood as an "active congestion," or "determination of blood" in the part.

I have already said, that we may believe that what is seen in the bat represents fairly the state of inflamed parts in all warm-blooded animals. I am quite conscious that the most one can see with the microscope, in these experimental inflammations, is but a faint picture of such inflammations as we have to consider in practice ; that it is very trivial in both its appearance and its results. Still, it is a picture of a disease of the same kind ; and a miniature, even faintly drawn, may be a true likeness. Besides, all that can be observed of the complete process of inflammation in man is consistent with what we can see in these lower and lesser creatures. The bright redness of an inflamed part testifies to the fulness of its blood-vessels, and the crowding of the corpuscles ; the occasional duskiess or lividity of the focus is characteristic of stagnation ; the throbbing in the part, and about it, and the full hard pulse in the ministrant arteries, are sure signs of obstruction to the passage of blood ; the gush of blood on cutting into the tissues near an inflamed part, or in bleeding from one of their veins, tells of the determination of blood in these, and of the tension in which all the containing blood-vessels are held.

It is particularly to be observed that the stagnant or retarded blood is not apt to coagulate. I have found it fluid after at least three days' complete stagnation, and so I believe it would remain till it is cleared away, unless the part sloughs. In the latter case it would coagulate, as it does in carbuncles and the like, which hardly bleed when we cut them through ; but, so long as the blood is fluid, though stagnant, it may be driven from the vessels with full force, as soon as an easy exit for it is made by cutting into the inflamed part, or opening one of its large veins. I need only here refer to Mr. Lawrence's well-known and instructive experiment. In a patient with an inflamed hand he made similar openings into veins in both arms. From the vein on the diseased side three times more blood flowed than from the vein in the healthy arm, in the same time. This increased flow represented at once the greater determination of blood about the focus of the inflammation, and the greater tension in which the walls of the blood-vessels, and, indeed, all the tissues of the inflamed and swollen part, were held.

Now, to what can we ascribe these changes in the movement of the blood ?

It has been commonly said that, as the vessels contract, therefore the movement of blood becomes more rapid in them, as when a river entering a narrow course moves through it with a faster stream ; and that then, as the vessels widen, so the stream becomes, in the same proportion, slower. But this is far from true. The stream becomes slower as the artery or vein becomes narrower by contraction ; and then, as the tube again dilates, the stream grows faster ; and then, without any appreciable change of size, it may become slower again, till complete stagnation ensues in at least some part of the blood-vessel.* I think I can be quite sure

* As Mr. Wharton Jones has shown, the retarded stream exists

that the velocity of the stream, in any vessel of an inflamed part, is not wholly determined either by the diminution or enlargement of the channel, or by the stagnation or congestion of blood in the vessels beyond. That much of the change in rate of movement depends on these conditions cannot be doubted; and it may seem unnecessary to question their sufficiency for the explanation of that change, after Mr. Wharton Jones's observations. But I think other forces must still be considered, whose disturbance may contribute to the result. Whether we name it vital affinity, or by any other terms, or (which may, as yet, be better) leave it unnamed, I cannot but believe there is some mutual relation between the blood and its vessels, or the parts around them, which, being natural, permits the most easy transit of the blood, but, being disturbed, increases the hinderances to its passage. Such hinderances appear to be produced by the addition of salts of baryta, or of potash, to the blood; and by an excess of carbonic acid in the blood that should traverse the minute pulmonary vessels. The presence of an excess of urea in the blood probably produces the like effect: and some of the facts connected with other than traumatic inflammations appear quite inexplicable without such an hypothesis as this. At any rate, the belief that the more or less rapidity of movement of blood through small vessels may depend on other than evident mechanical relations, cannot appear absurd to any one who has seen the movements of fluid in the Chara or Vallisneria, or any such plants, in which a circulation is maintained without any visible source of mechanical power.

II. I mentioned, as the second condition necessary to the

only when the vessel is generally contracted, and the accelerated stream when it is generally dilated: when a single vessel presents successive enlargements and diminutions of calibre, the rate of the stream in it diminishes in the former and increases in the latter.

healthy nutrition of a part, a right state and composition of the blood. In former lectures (p. 15, et seq.) I pointed out that, by this state, we must understand not merely such purity of the blood that chemistry cannot detect a wrong constituent in it, or a wrong quantity of any of the normal ones, but that natural constitution of the blood by which it is exactly adapted to every tissue that it has to nourish ; with an adaptation so exact that chemistry often cannot approach to the determination of whether it is maintained or lost.

That this adaptation is disturbed, in many cases of inflammation, is proved by the instances to which I shall have to refer, in which they plainly have their origin in morbid conditions of the blood. But I fear that the nature of this disturbance cannot yet be chemically expressed, and that the facts which chemistry has discerned, in the condition of the blood in inflammations, cannot yet be safely applied in explanation of the local process. For, first, we observe the phenomena of inflammation where we cannot suppose the whole blood disordered ; as after the application of a minute local stimulus, such as a foreign body on the conjunctiva : secondly, the changes observed in the blood during inflammations are not peculiar to that state, but are found more or less marked in pregnancy, and in other conditions in which no inflammatory process exists : and, thirdly, among the changes observed in inflammatory blood, the principal one, namely, the supposed increase of fibrine, is ambiguous ; it may be at once an increase of fibrine and of the white corpuscles of the blood. These two constituents of the blood, the fibrine and the white or rudimental corpuscles, cannot be well separated by any process yet invented ; and in all the estimates of fibrine, whether in health or in disease, the weight of the white corpuscles is included. Now in many inflammations these corpuscles are increased ; and in such cases we have no means of

clearly ascertaining how much of an apparent increase of fibrine is really such, and how much is due to the corpuscles entangled in the fibrine. Till this can be settled, I think we may not deduce any of the local phenomena of inflammation from the increase of fibrine in the blood; neither, more assuredly, can we trace, as some do, the fever and other general signs of inflammation to the abstraction of fibrine and albumen by the exudation from the blood.

The other principal changes of the blood in inflammation—the diminution of its red corpuscles and increase of water—are even less adapted to explain any of the phenomena of the local process. Whatever may be their strength or value as facts, they are as yet isolated facts, such as we cannot weave into the pathology of the disease.

I fear, too, that the structural condition of the blood will not, more than the chemical, help us to explain the phenomena of inflammation. Some of our most worthily distinguished pathologists have ascribed much to the existence of large numbers of the white blood-corpuscles, and their accumulation in the vessels of the inflamed part; indeed, they have taken this for the foundation of nearly their whole doctrine of inflammation, ascribing to it both the stagnation of the blood and the changes it is presumed to undergo; such as the increase of the fibrine, and many others. But the facts on which they have rested are unsound: their observations have been made on frogs, and do not admit of application to our own case, or, perhaps, to that of any warm-blooded animal.

In many frogs, especially in those that are young, or sickly, or ill-fed, the white corpuscles are abundant in the blood. They are rudimental blood-cells, such as may have been formed in the lymph or chyle; and in these cases they are probably either increasing quickly in adaptation to quick growth, or else relatively increasing because, through disease

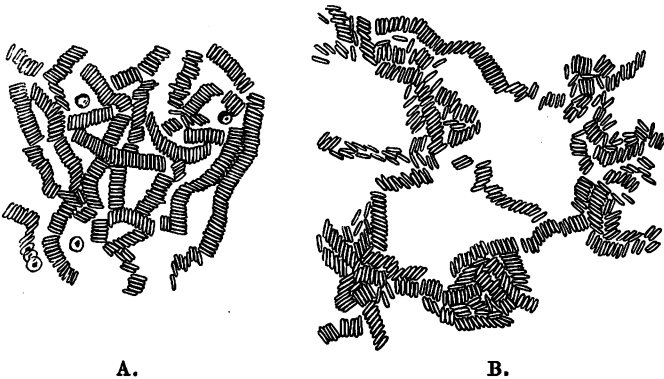
or defective nutriment, although their production is not hindered, yet their development into the perfect red blood-cells cannot take place. In either case, their peculiar adhesiveness making them apt to stick to the walls of the blood-vessels, they may accumulate in a part in which the vessels are injured or the circulation is slow, and thus they may sometimes augment the hinderances to the free movement of the blood. But I believe nothing of the kind happens in older or more healthy frogs, or in any ordinary inflammation in the warm-blooded animals. I have drawn blood from the vessels in the inflamed bat's wing, in which it was quite stagnant, and have found not more than one white corpuscle to 5000 red ones. I have often examined the human blood in the vessels of inflamed parts after death, and have found no more white corpuscles in them than in those of other parts. In blood drawn from inflamed parts during life, I have found only the same proportion of white corpuscles as in blood from the healthy parts of the same person. I therefore cannot but accord with the opinion, often expressed by Mr. Wharton Jones and Dr. Hughes Bennett, that an especial abundance of white corpuscles, in the vessels of an inflamed part, is neither a constant nor even a frequent occurrence; and I believe that, when such corpuscles are numerous in an inflamed part, it is only when they are abundant in the whole mass of the blood.* Now, as already stated, they are thus abundant in some cases of inflammation; especially, I think, in those occurring in people that are in weak health, and in the tuberculous; but, even in these cases, I have never seen an instance in which they were present in sufficient quantity to add materially to

* Dr. Hughes Bennett's researches on Leucocythæmia have shown that even the extremest abundance of white corpuscles in the blood has no tendency either to produce or to aggravate inflammations.

the obstruction of the blood in the inflamed part, nor one in which any influence of theirs could be suspected to alter peculiarly the constitution of the blood therein.

Mr. Wharton Jones was the first to describe accurately a remarkable condition presented by the red blood-cells in inflammation. When healthy blood is received on a glass plate and immediately examined, the corpuscles lie diffused in the liquor sanguinis, but in about half a minute run together into piles or rouleaux, which arrange themselves in a small-meshed net-work, as in the adjoining figure (A). But, if a drop of blood from a patient with acute rheumatism or inflammation be similarly examined, the piles of corpuscles are found to be instantly formed, and they cluster

FIG. 32.



into masses, in a net-work with wide meshes, as in the same figure (B). In such an arrangement they give the thin clot outspread on the glass the peculiar mottled pink and white appearance, which Mr. Hunter observed as one of the characters of inflammatory blood. The same condition is observed in the blood of pregnant women, and appears natural in that of horses; and in all these cases it may be regarded as the chief cause of the formation of the

buffy coat, inasmuch as the clustered blood-cells, sinking rapidly, generally subside to some distance below the surface of the liquid part of the blood, before the coagulation of the fibrine is begun.

Some have supposed that a similar adhesion of the blood-cells may occur in the vessels of an inflamed part, and produce, or materially affect, the inflammatory process. I have seen nothing of the kind in either the inflamed bat's wing, or in the vessels of inflamed organs examined after death. When the blood is not stagnant, the corpuscles are indeed closely crowded, but they are not clustered, nor do they appear adherent : neither does such clustering appear even in stagnant blood ; the change here appears to be a diffusion of the colouring matter, so that the outlines of individual blood-cells cannot be seen, and all the contents of the vessel present an uniform bright carmine tint.

But although we can see so little of the changes that may ensue in blood thus stagnant or much retarded, yet we may be nearly sure that the blood in an inflamed part does undergo important changes, when we remember what general effects, what constitutional disturbance, may ensue in the train of an inflammation of purely local origin. Changes probably ensue in the blood similar to some of those that we shall have to trace in the lymph effused from it into the parts around the vessels ; particles of fibrine may coagulate in it, and corpuscles like those of lymph may be formed and degenerate within it ; and these, when the stagnation is not constant, or is incomplete, or is passed away, may be carried into the general circulation, infecting the whole blood, exciting general disturbance, as in traumatic fever, or producing various and wide-extended suppurations, as in the purulent diathesis following local injury. All these, and many other concomitants of inflammation, may be reasonably ascribed, at least in part, to the changes

that the blood undergoes in the inflamed tissue; but I must repeat that nothing that either the microscope or chemistry has yet discerned will suffice to explain these changes: they belong rather to the theory than to the facts of inflammation.

III. The third enumerated condition for the healthy nutrition of a part is a certain influence of the nervous force. The change that this undergoes in an inflamed part is, therefore, next to be considered; or, rather, the evidence that it is changed is to be cited; for, as we have no exact knowledge of the manner in which the nervous force operates in ordinary nutrition, so neither can we tell how its operation is affected in inflammation, though we may be sure that it is not normal.

The expression that the nerves of an inflamed part are in an "excited" state, is suggested by the existence of pain; by a slight stimulus being acutely felt; by the natural heat, or a slight increase of the heat, being felt as a burning; and by the part being, even independent of any known stimulus, the seat or source of subjective pains and heat. But the very frequent cases in which pain exists, and abides long, without any other sign of inflammation, and the cases in which the pain bears no kind of proportion to those other signs, or to the effects of inflammation,—these may suggest that, besides this "excited" state of the nervous force, which is felt as pain in the inflamed part, there may be some other state by which the nervous force is more intimately connected with the inflammatory process; a state of disturbance, which may, indeed, be felt as pain, but which more properly affects the influence of the nervous force in the process of nutrition.

We obtain some evidence of the existence of such a state in the fact that, without relation to pain, it is communicable

from the nerves of inflamed parts to those of other parts ; in which parts, then, a kind of sympathetic inflammation may be generated. This transference or communication of the disturbance of nervous force is, indeed, evident enough in relation to that state which is felt as pain ; for pain is not limited to the inflamed part, but is diffused around it, and is, in sympathy, often felt where no other sign of inflammation exists. But besides, and sometimes, I repeat, independent of this condition which is felt as pain, the inflammatory condition, if I may so name it, of the nervous force may be similarly communicated or transferred. The simplest may be the most proving instances. Whoever has worked much with microscopes may have been conscious of some amount of inflammation of the conjunctiva, in consequence of over-work. Now the stimulus exciting this inflammation has been directly applied to the retina alone ; and I have often had a slightly inflamed left conjunctiva, after long working with the right eye, while the left eye has been all the time closed. I know not how such an inflammation of the conjunctiva can be explained, except on the supposition that the excited state of the optic nerve is transferred or communicated to the filaments of the nerves of the conjunctiva, generating in them such a state as interferes with its nutrition. It is true that, in these simpler cases, the retina is not itself evidently inflamed ; but after yet severer stimulus it commonly is so, and the conjunctiva shares in the evil effects of the communicated stimulus ; effects which we cannot ascribe to any alteration in the blood, or the size of the blood-vessels.

I may mention another case ; the occurrence of inflammation of the testicle in cases of severe irritation of the urethra. The most unexceptionable cases of the kind are those in which the irritation is produced by a calculus

impacted in a healthy urethra. I have a specimen,* in which extensive deposits of lymph and pus are seen in the testicle of a man, in whose urethra a portion of calculus was impacted after lithotripsy. Here is such an inflammation as we cannot refer to disease of the blood, and attended by such changes as we cannot explain by any enlargement or paralysis of the blood-vessels: nor do I know how it can be at all explained, except by the disturbance of the exercise of the nervous force in the testicle, which disturbance was excited by transference from the morbidly affected nerves of the primary seat of irritation in the urethra.

In like manner, I believe that the extension or transference of inflammation, after or with pain, may be ascribed, at least in part, to the coincident transference of the disturbed plasturgic force of the nervous system. In paroxysms of neuralgia, we see sometimes a transient inflammatory redness or œdema of the part; so, when a more abiding pain has been excited, by sympathy with some inflamed part, there may presently supervene the more palpable effects of inflammation.

I feel that in discussing such a point as this, one passes from the ground of demonstrable facts; but there is, I hope, less fault in this than in the belief that the very little we can see of a morbid process can guide us to its whole pathology. When we look at an inflamed part, we should not think that, if we could see its blood-vessels and test its blood, we should detect all that is in error there: rather, we should think that all the forces are at fault which should be concurring to the due maintenance of that part; and while we are ignorant of the nature of some of these forces, it is better that their places in our

* Museum of St. Bartholomew's Hospital, Ser. xxviii. No. 55.

minds should be occupied by reasonable hypotheses, than that they should be left blank, or be overspread with the tinge of one exaggerated theory, such as those are which ascribe all inflammation to a change in some one of the conditions of nutrition.

IV. The last condition necessary to healthy nutrition in a part is the natural or healthy state of the part itself.

The manner in which this is changed in the inflammatory state cannot be well considered till an account has been given of the exudation that takes place from the blood-vessels, and of some other changes in the very process of nutrition. Let it, for the present, suffice to say (1), that a disturbance in the condition of a part may be the cause, independently of blood-vessels or nerves, of an inflammation in it, as in wounds and other injuries of non-vascular and other parts; and (2) that when an inflammation is thus, or in any other way, established, the proper elements of the affected part continually suffer change. Such changes are due, first, to the degenerations which, as in other cases of hindered nutrition, the elemental structures spontaneously undergo: and, secondly, to the penetration of the inflammatory product into them and the interstices between them. Each of these sources of change may, in different cases, predominate: in certain cases, it is probable that one alone of them may be effective; and either or both of them may affect either the elemental structures that are already perfected, or, probably in a greater degree, the materials that are in progress of development.

All these things will be subjects of future lectures; but, before proceeding to them, let me add a few words, to prevent misunderstanding.

I have spoken so separately of the changes in the several conditions of nutrition, that I may have seemed to imply

that inflammation may consist in the disturbance sometimes of one, sometimes of another, of these states. It is true that inflammation may have its beginning in any one of these conditions,—as in an alteration of the blood in rheumatism, in an alteration of the nervous force in irritation of the retina, in an alteration of the proper elements of the tissue in inflammation of the cornea; but, probably, it is never fully established without involving in error all the conditions of nutrition; and both the manner in which they may be thus all involved, and their subsequent changes, should be studied as concurrent events, rather than as a series of events, of which each stands in the relation of a consequence to one or more of those that preceded it. Nowhere more than here is the mischief evident, of trying to discern in the economy of organic beings a single chain or series of events, among which each may appear as the consequence of its immediate predecessor: most fallacious is the supposition that, starting from a turgescence and stagnation of blood in the vessels of a part, we may explain the pain, the swelling, the heat, and all the other early and consecutive phenomena of inflammation. The only secure mode of apprehending the truth in this, as in every other part of the economy of living beings, is by studying what we can observe as concurrent, yet often independent, phenomena, or as events that follow in a constant, but not necessarily a consequent, order.

LECTURE XIV.

PRODUCTS OF INFLAMMATION.

THE state described in the last lecture may, without further change, cease and pass by, and leave the part, apparently, just as it was before. And there are two chief modes in which this may happen ; namely, by resolution or the simple cessation of the inflammation, and by metastasis, in which, while the inflammation disappears from one part, it appears in another. So far as the inflamed part itself is concerned, I believe the changes are in both these cases the same, and consist in a more or less speedy return to the normal method of circulation, and the normal apparent condition of the blood and of the nerves ; the tissue itself presenting no change of structure.

I do not know that any description of the process of recovery, from the inflammatory state, would tell more than is implied by calling it a gradual return to the natural state, a gradual retracing of the steps by which the natural actions had been departed from. As it has been watched in the frog's web, and in the bat's wing, the vessels, that were filled with quick-flowing blood, become narrower, the streams in them also becoming slower, and less gorged with red blood-corpuscles, till the natural state is restored. The pulsating or slower streams are equalized with those about them, and, gradually making their way into the stagnant columns, drive them on or disperse them. In

the frog, clusters of blood-corpuscles have been seen to become detached, by a stream breaking-off portions of the stagnant blood, and then to float into the current, where, gradually, they disperse. So, too, in the tadpole, after injury, I have seen fragments of fibrine, washed from the blood in the vessels of the injured part, floating in some distant vessels. Dr. Kirkes's observations leave no doubt that similar changes may occur in the warm-blooded animals, and may be the source of great evil, by carrying the materials of diseased or degenerate blood from a diseased organ to one that was previously healthy (p. 143.)

It may be difficult to explain this recovery in the case of complicated inflammations. When a slight mechanical stimulus has been applied, and the vessels, after contracting, have dilated, we may see some signs of weakened muscular power, in the fact that the same stimulus will not make them contract again; and then their gradual recovery may be the consequence of their regaining their weakened and exhausted power, just as a wearied muscle does when left *atr est*. This must always be one element in the recovery of the natural state by a part that has been inflamed; indeed, it is probably that part of recovery which is most slowly achieved. Still, it is, probably, only one element in the process of recovery. In an inflammation in which all the conditions of nutrition are at fault, each must recover its normal state; but, of the manner in which they severally do so, we have no knowledge. The order in which they are restored is scarcely less uncertain: probably it is not constant, but may depend, in great measure, on the order in which they were involved in error. But we have no clear facts in this matter; only we may observe, that in many cases, if we correct the error of one of the conditions of nutrition, the rest will be more apt to correct themselves.

Thus, of the remedies for inflammation, few can act upon more than one of the conditions on which it depends ; yet they may be remedies for the whole disease ; for, as it were, by abstracting one of its elements, they destroy the consistence and mutual tenure of the rest.

The cessation of the disease may be regarded as the most perfect cure of which inflammation admits. It is in many cases an unalloyed advantage ; but in some it is not so, though the local change may be the same ; for materials accumulated in the stagnant blood of the inflamed part, or absorbed from its morbidly altered tissues, may, when the inflammation subsides, pass into the general current of the blood, and infect its whole mass, or disturb the nutrition of an organ more important than that which they have left. Such are the events in the metastasis of gout, and the premature subsidence of cutaneous eruptions.

We have now considered how, in the inflammatory state, the conditions of nutrition are affected : and, in a future lecture, I hope to show how a change in any one of these conditions may appear as the cause of inflammation, by being the first in the series of changes, in which, in the complete morbid process, they are all involved.

The next subject may be the changes in the nutritive process itself ; those which are commonly observed as the effects of inflammation, when the process does not subside in the manner just described. They are chiefly manifest (1) in a change of the material that is separated from the blood into or upon the affected tissue ; and (2) in changes of the tissue itself. These changes usually coincide : and it may be generally said, that in all inflammations, at least of vascular parts, there is at once an increased exudation of fluid from the blood-vessels, and a deterioration of the structures,

of the affected part. Either of these events may, in certain cases, predominate over the other ; in some instances, one alone of them may be observed ; but they so generally concur, that a natural division of the inflammatory changes of the nutritive process may be into those that are *productive* and those that are *destructive*.

Adopting, then, such a division, as of the effects of inflammation, the description of the productive changes will include the histories of the several effusions or exudations from the blood-vessels into the inflamed part, their developments, degenerations, and other changes. In the account of the destructive effects may be comprised that of the various defects of nutrition, the degeneration, absorption, ulceration, and death, to which the proper elements of the inflamed part, and, with them, the products of the inflammation, are liable.

I proceed, then, to these histories ; and first of the *products of inflammation or inflammatory exudations*.

The materials that may be effused from the blood-vessels of inflamed parts are chiefly these : serum ; blood ; lymph, or inflammatory exudation especially so-called ; and mucus. The last two may be regarded as primary forms, from which, by development, or degeneration, many others may be derived.

I. *The effusion of serum*, except as the result of the lowest degrees of inflammation, or as a diluent of other products, is probably a rare event. That which is usually regarded as a serous effusion in inflammation, is, in many cases, a fluid that contains fibrine, and resembles the *liquor sanguinis* rather than mere serum. It is this kind of effusion on which Vogel* has fully written, under the designation of "Hydrops fibrinosus." A good example of it may be seen

* Pathologische Anatomie, p. 23.

in the fluid contained in blisters, raised by the action of cantharides or heat applied to healthy persons. And another form of liquid effusion differs from serum, in that, though it does not coagulate, it contains a material capable of organization into cells : such is the fluid that fills the early vesicles of herpes, eczema, and some other cutaneous diseases.

The fluid that contains fibrine, and is most generally described as a serous effusion, may have the ordinary aspect of serum ; more rarely it is colourless or opalescent, like the liquid part of the blood which one sees collecting for the formation of a buffy coat. The fibrine that it contains may remain in solution, or without coagulation, for an indefinite time within the body, but will coagulate readily when withdrawn. For example, the so-called serous effusion, which is abundant in the integuments near the seat of an acute inflammation in deeper parts, and which flows out like a thin yellowish serum after death, will soon form a soft jelly-like clot, that is made succulent with the serum soaked in it. The fibrine appears tough, opaque-white, and stringy, when the fluid is expressed from it, and shows all the recognized characters of the fibrine of the blood. Thus, to mention but one case which was remarkable for the delay of the coagulation. A man received a compound fracture of the leg, and it was followed by phlegmonous inflammation and abscesses up the limb. As soon as the inflammation had subsided enough, the limb was amputated ; and, three days afterwards, in examining it, a quantity of serous-looking fluid oozed from the cut through the integument. I collected some of this, and, after four hours, it formed a perfect fibrinous clot ; yet the fibrine in this case had remained among the tissues without coagulating, for three days after the death of the limb, and for many more days during the life of the patient.

Such, too, are the effusions like serum in blisters raised on the skin by heat or cantharides ; such the serous effusions of peritonitis, as in hernia, and of many cases of pleurisy and pericarditis. All these fluids, though they may retain their fluidity for weeks or months within the body, during life, may yet coagulate when they are removed from the body. With these, too, may be reckoned, but as the most nearly serous of the class, the fluid of common hydrocele ; for I have seen a small coagulum form in such fluid spontaneously ; and the presence of fibrine may always be proved by the formation of a clot, when a small piece of blood-clot, or of some organized tissue, is introduced into the fluid.

One can rarely tell why the coagulation of the fibrine in these cases should be delayed : there are, here, the same difficulties as are in all the exceptions from the general rules of the coagulation of the blood. But, it may be observed, the delay of the coagulation is a propitious event in all these cases ; for, so long as the effusion is liquid, absorption may ensue on the subsidence of the inflammation ; but absorption is more unlikely and tardy when the fibrine has coagulated. Thus, large quantities of fluid, which, we may be sure, contained fibrine, may disappear by absorption from the seats of acute rheumatism or gout, or from the pleura or peritoneum, or from the subcutaneous tissues, and leave only inconsiderable adhesion, or thickening of the affected part. But, on the other hand, when, in the same class of cases, the fibrine coagulates, it may be organized, and the usual consequent phenomena of inflammation will ensue. Thus it is in the cases of what has been called solid œdema, where, in the neighbourhood of acute inflammation, an effusion long abides with all the characters of ordinary serous œdema ; but, at length, the tissues are found indurated and adhering, the œdema

having consisted in the effusion of serum with fibrine, which has coagulated and become organized in the seats of its effusion. Thus, too, it is that the damage done by rheumatism in a part is, on the whole, in direct proportion to the length of time it has subsisted there, and the opportunity given by time for the coagulation of the fibrine.

From what I have said, it will appear that nearly all of what are called serous effusions in inflammation are effusions of fluid containing either fibrine, or a material that will organize itself into cells. But it may be said that we often find, after death, effusions which contain nothing but the constituents of serum, though produced in an inflammatory process. If, however, we examine these cases more closely, they will appear consistent with the others: some of the fluids will coagulate if kept for several hours, or if mixed with other serous fluids, or if fragments of fibrine be placed in them; in others we find flakes of molecular matter, indicating that fibrine had been already coagulated, or that corpuscles had been formed, but that subsequently they were disintegrated, or even partially dissolved; and in some we may believe that similar materials were decomposed in the last periods of life, or after death.

On the whole, it seems sure that an effusion of serum alone is a rare effect of inflammation, and that generally it is characteristic of only the lowest degrees of the disease. Among the instances of it are, probably, the cases of the chronic forms of hydrops articuli, some forms of hydrocephalus, and some cases of inflammatory cedema of the mucous membrane, as in the cedema of the glottis, and chemosis of the conjunctiva.

In the nearly constant fact of the presence of organizable materials in the products of inflammation, we have one evidence of the likeness between inflammation and the normal process of nutrition, and of its difference from the merely

mechanical obstructions or stagnations of the blood. In these, the material effused from the blood is usually the merely serous part : the fluids of anasarca and ascites will not coagulate ; they present neither fibrine nor corpuscles, except in the cases of extremest obstruction, when, as in cases of ascites from advanced disease of the heart, one may find flakes of fibrine floating in the abdomen, or masses of it soaked and swollen-up with serum.*

II. The second of the so-called inflammatory effusions is Blood.

Among the effusions of blood that occur in connection with the inflammatory process, many, as Rokitansky has explained, are examples of hæmorrhage from rupture of the vessels of lymph recently become vascular. The new vessels, or their rudiments, are peculiarly delicate ; and being apt to rend, like the vessels of new granulations, with a very slight force, especially when they are made turgid or dilated by an attack of inflammation of the lymph, they will commonly be sources of considerable bleeding. So, for example, it probably sometimes happens when, as the expression is, an hydrocele is converted into an hæmatocele ; some lymph

* It has been supposed that, in mechanical dropsies, the effusion of serum takes place through the walls of the small veins, and that in inflammations an equally mechanical effusion of liquor sanguinis takes place through the walls of the capillaries and small arteries ; and this supposition is assumed for an explanation of the difference between a dropsical and an inflammatory effusion. But I think that in a merely mechanical obstruction of the blood, as by disease of the heart, or compression of veins, the pressure of the blood cannot but be increased alike in the veins, capillaries, and arteries, and that, in correspondence with this uniformly diffused pressure, the increased effusion will take place at once through all these vessels, in direct proportion to the permeability of their walls.

becoming vascular, and being submitted to even slight violence, its vessels break, and blood is poured into the sac. So, too, probably, it is with many or all the cases of what are called hæmorrhagic pericarditis. But of these, which may be called *secondary hæmorrhages*, I will speak hereafter.

Primary effusions of blood, *i. e.* effusions of blood poured from the ruptured vessels of the inflamed part, and mingled with the lymph or other inflammatory product, appear to be rare in some forms or localities of inflammation, but are almost constant in others. Thus, *e. g.* in pneumonia, extravasated blood-corpuscles give the sputa their characteristic rusty tinge. In the inflammatory red softening of the brain, blood is also commonly effused ; and the condition of the vessels, which I described in the last lecture, (p. 299) may well account for their rupture. There are also other cases of these effusions of blood in inflammation ; but I believe these imply no more than accidents of the disease.

We must not confound with hæmorrhages the cases in which the inflammatory products are merely blood-stained, *i. e.* have acquired a more or less deep tinge of blood, through the oozing of some dissolved colouring matter of the blood. The natural colour of inflammatory exudations is greyish or yellowish-white, and, even when they have become vascular, their opacity in the recent state prevents their having any uniform tint of redness visible to the naked eye. When inflammatory products present the tinge of redness, it is either because of hæmorrhage into them, or because they have imbibed the dissolved colouring matter of the blood : and when this imbibition happens during life, or soon after death, it is important, as implying a cachectic, ill-maintained condition of the blood, in which condition the colouring matter of the corpuscles becomes

unnaturally soluble. Thus blood-stained effusions are among the evil signs of the products of inflammation during typhus, and other low eruptive fevers, in syphilis, and in scurvy.

III. Serous effusions, then, appear to be rare as the results of inflammation; and effusions of blood are but accidents in its course. The characteristic primary product of the inflammatory process is the liquid which the elder writers named "lymph," "coagulating or coagulable lymph," and which more lately has been called "exudation," or "inflammatory exudation."* It is, probably always, at its first exudation, a pellucid liquid, which passes through the blood-vessels, especially the capillaries,† of the inflamed part; and its most characteristic general properties are, that it is capable of spontaneously organizing itself; even while its external circumstances remain apparently the same, and that, thus organised, it may proceed by development to the construction of tissues like the natural structures of the body.

* It is to be regretted that we have no distinctive appellation for this substance. To call it "lymph" is objectionable, while, already, the same word is employed for the fluid in the lymphatic vessels, with which it is probably not identical, though they are in many respects similar. And the term "exudation" is yet more objectionable, since it has to be employed as well for the act of separation from the blood, as for the material separated; or, even if it be limited, as the Germanized "Exsudat" is, to what has oozed from the blood, still, it is equally applicable to all the liquid products of inflammation, and not more to any one of them than to the serum of a dropsy, or the material separated for normal nutrition. On the whole, in accordance with the generally good rule of retaining an old term till a better new one is proposed, the words "inflammatory lymph" appear least improper.

† Or, perhaps, only from them: see a remarkable case by Mr. Bowman; Lectures on the Eye, p. 44.

The form assumed by inflammatory lymph in its primary organization is not always the same. There are, rather, two chief forms of organization, which, though they are often seen mixed in the same material, are yet so distinct as to warrant the speaking of two varieties of inflammatory lymph, by the names of *fibrinous* and *corpuscular*.*

To the fibrinous variety belong, as typical examples, all the instances in which inflammatory lymph, effused as a liquid, coagulates into the solid form, and yields, when the fluid is pressed from the solid part, either an opaque-whitish, elastic substance, having the general properties of the fibrine of the clot of blood, or the softer, and, as it is supposed, the less perfect or less developed, fibrine of the chyle or the absorbed lymph.

Such examples of nearly pure fibrinous inflammatory lymph are found, in the cases already referred to, among what have been supposed to be effusions of mere serum. Such are many instances of effusions produced by blisters and other local irritations of the skin in healthy men : such, too, are most of the effusions in acute inflammations of serous membranes, especially in those of traumatic origin, and in those that occur in vigorous men. If, in any of these cases, the lymph be examined after coagulation, or, possibly, deposit in the solid form, it may be hard to distinguish it from the fibrine of the clot of blood. The layers of fibrinous lymph thus formed may be known to the naked eye, when on serous membranes, by their peculiar elasticity and toughness, their compact and often laminated structure, their greyish or yellowish-white and semi-transparent aspect, and their close adhesion to the membrane, even before they have become vascular.

* Corresponding varieties are distinguished or implied by Vogel, p. 30, Dr. Andrew Clark (*Medical Gazette*, vol. xlii. p. 286), and others.

In the corpuscular variety of inflammatory lymph, no coagulation, in the ordinary sense of the word, takes place ; but corpuscles form and float free in the liquid part. Typical examples of this variety are found in the early-formed contents of the vesicles of herpes, eczema, and vaccinia ; in the fluid of blisters raised in cachectic patients ; in some instances of pneumonia ; and in some forms of inflammation of serous membrane.

The lymph- or exudation-corpuscles or cells, found in such lymph as this, present numerous varieties in their several developments and degenerations ; but, in their first appearance, resemble very nearly the primordial condition of the corpuscles of chyle and absorbed lymph, the white corpuscles of the blood, and those of granulations.*

The first discernible organic form in the lymph of herpes, for example, is that of a mass of soft, colourless, or greyish-white substance, about $\frac{1}{3300}$ th of an inch in diameter, round or oval, pellucid, but appearing, as if through irregularities of its surface, dimly nebulous or wrinkled. It does not look granular, nor is it formed by an aggregation of granules ; nor, in its earliest state, can any cell-wall be clearly demonstrated, or any nucleus, on adding water. But, in a few hours, as the development of this cell-germ proceeds, a pellucid membrane appears to form as a cell-wall over its whole surface ; and now, when water is added, it penetrates

* I have already (p. 184) referred to this fact of a single primordial form existing in the rudiments of many structures, which in later periods of their existence are widely different. It is a repetition of a fact in the first development of beings. In the early embryo, the most various ultimate forms are developed from a nearly uniform mass of primordial embryo- or germ-cells. And so it is in later life ; many of both the normal and the morbid structures start from one primordial form, and, thence proceeding, diverge more and more widely in attaining their several perfect shapes.

this membrane, raising-up part of it like a clear vesicle, while upon the other part the mass retreats, or subsides, and appears more nebulous or grumous than before. In yet another state, which appears to be a later stage of development, the action of water not only raises up a cell-wall, but breaks-up and disperses the outer part of the contents of the cell, and exposes in the interior a nucleus, which is commonly round, clearly defined, pellucid, and attached to the cell-wall.

From the various developments of these cells are derived, in the products of inflammation, all the several forms of corpuscles that are described as plastic cells, fibro-cells, caudate or fibro-plastic cells, and some forms of filaments. These correspond with the development of granulation-cells already described (p. 184). On the other hand, from their various degenerations, descend those known as pus-corpuscles, granule-cells, granule-masses, inflammatory globules, and much of the molecular and debris-like matter that makes inflammatory effusions turbid.

The examples of inflammatory lymph which I have quoted are such as may be considered typical of the two varieties : the first, in which, spontaneously coagulating, it presents fibrine, either alone or mingled with very few corpuscles ; and the second, in which corpuscles are found alone, or with only a few flakes of fibrine. But, in a large number of examples of inflammatory lymph, the fibrine and the corpuscles occur together, mixed in various proportions, the one or the other preponderating. Such instances of mixed lymph are found in the fluid of blisters in all persons not in full health ; in all but the freshest inflammations of serous membranes ; in most of the inflammatory deposits in cellular tissue, and in most of the viscera ; and in the false membranes of croup and other similar inflammations of mucous membranes.

Now, in general, and in the first instance, the propor-

tions of fibrine and of corpuscles that are present in the lymph of an inflammation, will determine the probability of its being organized, or of its degenerating. The larger proportion of fibrine in any specimen of inflammatory lymph (provided it be healthy fibrine), the greater is the probability of its being organized into tissue; such as that of adhesions, indurations, and the like. On the other hand, supposing the other conditions for development or degeneration to be the same, the larger the proportion of corpuscles in lymph, the greater is the probability of suppuration or some other degenerative process, and the more tardy is any process of development into tissue. In other words, the preponderance of fibrine in the lymph is generally characteristic of the "adhesive inflammation;" the preponderance of corpuscles, or their sole existence, in the liquid, is a general feature of the "suppurative inflammation."*

* In this view, the fibrinous and the corpuscular varieties of lymph nearly correspond with those which Dr. Williams, in his Principles of Medicine, and others, have named plastic and aplastic; but they do not completely do so. In different instances of both varieties, very diverse degrees of plastic property may be found; and the occurrence of development or degeneration depends on many things besides the primary characters of lymph. They more nearly correspond with what Rokitansky (*Pathologische Anatomie*, i. 96) has distinguished as fibrinous and croupous; the varieties which he names croupous α , β , and γ , representing the several grades of lymph in which the corpuscles gradually predominate more and more over the fibrine, and assume more of the characters of the pus-cell. I would have used his terms, but that, in this country, we have been in the habit of considering croupous exudations to be peculiarly fibrinous.

I described the healing of subcutaneous wounds as usually accomplished by a fibrinous material, and that of open wounds by cells developing into fibres (p. 180). These materials exactly correspond in appearance and modes of development with the fibrinous and corpuscular varieties of inflammatory lymph. And what was then said of the liability of the cells formed in the repair of open wounds to be

The knowledge of this fact may help us to learn the several conditions on which, in the first instance, depend these two forms of inflammation, the contrast between which has lost none of its importance since the time of Hunter. I will therefore at once enter on this question ;— what are the conditions that determine the production of one or the other variety of lymph ; the fibrinous, which, apt for development, is as the symbol of the adhesive inflammation, or the corpuscular, which, prone to degenerate, may be that of the suppurative inflammation ?

The conditions which are chiefly powerful in determining the character and tendency of inflammatory lymph, are three ; namely—

1. The state of the blood ;
2. The seat of the inflammation ;
3. The degree of the inflammation.

First, in regard to the influence of the state of the blood in determining the characters of an inflammatory product, Rokitansky has happily expressed it by saying that “ the product of the inflammation exists, at least in part, in its germ preformed in the whole blood.” Some, indeed, have supposed that lymph is only the liquor sanguinis exuded in excess through the walls of the blood-vessels ; but of this opinion we cannot be sure, and many facts, such as the occurrence of inflammatory lymph which does not spontaneously coagulate, *e. g.* in herpes, will not agree with it. Still, it is not difficult to show that a certain character is commonly impressed by the state of the blood on the inflammatory product from it.

arrested in their development, or to degenerate into pus-cells and lower forms, and of the consequent insecurity of this mode of repair as compared with the subcutaneous, is confirmed by the corresponding history of the two varieties of lymph.

I will not refer here to the cases of inoculable diseases, in which some of the morbid material that was in the blood may be incorporated with the product of a local inflammation, though in these the correspondence of the blood and the inflammatory product is manifest enough; but I will refer to cases that may show a more general correspondence between the two, a correspondence such that, according to the state of the blood, so is the lymph more fibrinous or corpuscular; more characteristic of the adhesive, or of the suppurative inflammation.

Some of the best evidence for this is supplied by Rokitsansky, in the first volume of his *Pathological Anatomy*; a work that I cannot again mention without a tribute of respect and admiration for its author, since in it, more than in any other of his writings, he has proved himself the first among all pathologists, in knowledge at once profound, minute, and accurate, in power of comprehending the vastest catalogue of single facts, and in clear discernment of their relations to one another, and to the great principles on which he founds his systems. In this work, he has shown clearly, that the characters of inflammatory deposits, in different diatheses, correspond very generally and closely with those of the coagula found in the heart and pulmonary vessels; and that, in general, the characters of inflammatory lymph, formed during life, are imitated by those of clots found in the body after death, when the fibrine of the blood may coagulate very slowly, and in contact with organic substances.

Other evidence may be obtained by examining the products of similar inflammations excited in several persons, in whom the state of the blood may be considered dissimilar. And here, the evidence may be more pointed than in the former case; for, if it should appear that the same tissue, inflamed by the same stimulus, will, in different

persons, yield different forms of lymph, we shall have come near to certainty that the character of the blood is that which chiefly determines the character of an inflammation.

To test this matter, I examined carefully the materials exuded in blisters, raised by cantharides-plaisters, applied to the skin in thirty patients in St. Bartholomew's Hospital. Doubtless, among the results thus obtained, there might be some diversities depending on the time and severity of the stimulus applied ; still, it seemed a fair test of the question in view, and the general result proved it to be so. For, although the differences in the general aspects of these materials were slight, yet there were great differences in the microscopic characters ; and these differences so far corresponded with the nature of the disease, or of the patient's general health, that, at last, I could generally guess accurately, from an examination of the fluid in the blister, what was the general character of the disease with which the patient suffered. Thus, in cases of purely local disease, in patients otherwise sound, the lymph thus obtained formed an almost unmixed coagulum, in which, when the fluid was pressed out, the fibrine was firm ; elastic, and apparently filamentous. In cases at the opposite end of the scale, such as those of advanced phthisis, a minimum of fibrine was concealed by the crowds of corpuscles imbedded in it. Between these were numerous intermediate conditions which it is not necessary now to particularise. It may suffice to say that, after some practice, one might form a fair opinion of the degree in which a patient was cachectic, and of the degree in which an inflammation in him would tend to the adhesive or the suppurative character, by these exudations. The highest health is marked by an exudation containing the most perfect and unmixed fibrine ; the lowest, by the formation of the most abundant corpuscles, and their nearest approach,

even in their early state, to the characters of pus-cells. The degrees of deviation from general health are marked, either by increasing abundance of the corpuscles, their gradual predominance over the fibrine, and their gradual approach to the characters of pus-cells ; or, else, by the gradual deterioration of fibrine, in which, from being tough, elastic, clear, uniform, and of filamentous appearance or filamentous structure, it becomes less and less filamentous, softer, more paste-like, turbid, nebulous, dotted, and mingled with minute oil-molecules.

I would not make too much of these observations. They are not enough to prove more than the rough truth, that the products of similar inflammations, excited in the same tissue, and by the same stimulus, may be in different persons very different, varying especially in accordance with the several conditions of the blood. Yet, simple as the observations are, they may illustrate what often seems so mysterious ; namely, the different issues of severe injuries inflicted on different persons. To what, more than to the previous or some acquired condition of the blood, can we ascribe, in general, the various consequences that follow the same operations on different patients ? The local stimulus, and the conditions by which the inflammatory product finds itself surrounded, may be in all alike ; but, as in the simpler case of the blister, the final events of the inflammation are according to the blood.

I cannot doubt that a yet closer correspondence between the blood, and the products of inflammation derived from it, would be found in a series of more complete observations ; in such, for instance, that the characters of the blood drawn during life, or, much better, of the clots taken from the heart after death, might, in a large number of patients, be compared with those of inflammatory exudations produced, as in the cases I have referred to, by the

same stimulus applied to the same tissue. In the few cases in which I have been able to make such examinations, this view has been established; and it is confirmed by the parallelism between the varieties of lymph that may be found in blisters, and the varieties of the fibrinous coagula in the heart described by Rokitansky.* The varieties of solidified fibrine which he classes as fibrines 1, 2, 3, 4, are very nearly parallel with what I have enumerated as the stages from the best fibrinous to the corpuscular lymph; and, as I have already implied, he regards these clots found in the heart and vessels as representing the different "fibrinous crases" or diatheses of the blood.

I mentioned, as the second condition determining the character of inflammatory lymph, the seat or tissue which the inflammation occupies.

I need hardly remind you that, since the time of Bichat, there has been a general impression that each tissue has its proper mode and product of inflammation. The doctrines of Bichat on this point were, indeed, only the same as Mr. Hunter held more conditionally, and, therefore, more truly; but they gained undisputed sway, among the principles of that pathology which rested on general anatomy as its foundation.

The facts on which it is held that, in general, each part or tissue is prone to the production of one certain form of inflammatory exudation, are such as these: that, *e. g.* in the apparently spontaneous inflammations of the skin, lymph with corpuscles alone is produced, as in herpes, eczema, erysipelas; that in serous membranes, the lymph is commonly fibrinous, and has a great tendency to be organized, and form adhesions; that in mucous membranes there is as

* Pathologische Anatomie, B. i. p. 142.

great a tendency to suppuration ; that in the lungs, both fibrine and corpuscles are abundant in the lymph, and the corpuscles have a remarkable tendency to degenerate into either pus-cells or granule-cells ; that in the brain and spinal cord the tendency is to the production of a preponderance of corpuscles, that quickly degenerate into granule-cells ; while in the cellular tissue, both fibrine and corpuscles appear, on the whole, equally apt to degenerate into pus, or to be developed into filamentous tissue.

Now these are, doubtless, facts ; but the rules that it is sought to establish from them are not without numerous exceptions. The instances I have lately quoted show that, in one tissue at least, the skin, the products of inflammation will vary according to the condition of the blood, although the inflammation be always similarly excited by the same stimulus. So, too (as Mr. Hunter remarks*), if it were the tissue alone that determines the character of an inflammation, we ought to have many forms of inflammation in the same stump after amputation ; whereas, all is consistent ; or the differences among the tissues are only differences of degree : they all adhere, or all granulate and suppurate, or all alike inflame and slough.

It is therefore not unconditionally true that each tissue has its proper mode and product of inflammation. It has been too much overlooked that a morbid condition of the blood, or perhaps even of the nervous force, may determine, at once, the seat of a local inflammation, and the form or kind of inflammatory product. Thus, *e. g.* the variolous condition of the blood may be said to determine, at once, an inflammation of the skin, and the suppurative form of inflammation ; for, in variola, whatever and wherever inflammations arise, they have a suppurative tendency. So,

* Works, vol. iii. p. 313.

in rheumatism, whether it be seated in muscles, ligaments, or synovial membranes, in serous membranes, or in fibrous tissues, there appears the same tendency to serous and fibrinous effusions, which are slow to coagulate or organize, and even less prone to suppuration. The same might be said of the local inflammations that are characteristic of typhus and of gout, and, I believe, of all those diseases in which a morbid condition of the blood manifests itself in some special local error of nutrition. And all these cases are illustrative of the general truth, that each morbid condition of the blood is prone both to produce an inflammation in a certain part, and to give to that inflammation a certain form or character.

Cases, however, remain, that prove some influence of the tissue in determining the product of its inflammation ; in determining, I mean, the primary form, as well as the later development, of the product : and the true influence of the tissue in this respect is best shown in some of the cases in which the inflammation, excited, apparently, by the same means, has happened coincidently in two or more very different parts in the same person. Thus we may find, *e. g.* that, in pleuro-pneumonia, the lymph on the pleura is commonly more fibrinous than that within the substance of the lung ; and adhesions may be forming in the one, while the other is suppurating. In cases of coincident pneumonia and pericarditis, the lymph in the lung may appear nearly all corpuscular, and all the corpuscles may show a tendency to degenerate into granule-cells, while the lymph on the pericardium may have a preponderance of fibrine, and what corpuscles it has may tend to degenerate into pus-cells. So, too, one may find, in the substance of an inflamed synovial membrane, abundant lymph-cells, while all the exudation on its surface may appear purulent.

I have said that the fluid of the sac in cases of strangu-

lated hernia coagulates on withdrawal from the body : it may be regarded as a mixture of serum and fibrinous lymph from the inflamed serous membrane. But, in a case in which I was able to examine a pellucid fluid contained in large quantity in the cavity of the strangulated intestine, and which appeared to be the nearly pure product of inflammation of the mucous membrane, there was no fibrine ; the fluid was albuminous, and contained abundant lymph-cells.

Other instances of this might be mentioned. These, however, may seem enough to establish the influence of the second condition that I mentioned ; namely, the seat of an inflammation, as determining the character of its products.

The third condition on which the character of the lymph chiefly depends is, the degree of the inflammation producing it.

The influence of a tissue, in determining the character of the lymph formed in its inflammations, may be in some measure explained, by believing that the primary product of inflammation is, often, a mixture of lymph, and of the secretion, or other product, of the inflamed part, more or less altered by the circumstances of the inflammation.

When it is seen that in inflammations of bone the lymph usually ossifies ; in those of ligament, is converted into a tough ligamentous tissue ; and that, in general, lymph is organized into a tissue more or less corresponding with that from whose vessels it was derived ; it is usually concluded that this happens under what is called the assimilative influence of the tissues adjacent to the organized lymph. But we may better explain the facts, by believing that the material formed in the inflammation of each part partakes, from the first, in the properties of the natural products of that part ; in properties which, we know, often determine the mode of formation independently of any assimilative force (p. 59).

We have some evidence of this in the products of inflammation of secreting organs, the only structures of which we can well examine the natural products in their primary condition. In a moderate amount of inflammation of a secreting gland, the discharge is usually a mixture of the proper secretion in a more or less morbid state, and of the inflammatory product. Thus we find morbid urine mixed with fibrine, or albumen, or pus. In cases of inflamed mucous membranes, the product is often a substance with characters intermediate between those of the proper mucous secretion and those of lymph. Or, again, in serous membranes, we may perceive a relation between their natural secretion and the usual products of their inflammation.

Now, these considerations are equally illustrative of the influence of the third among the conditions enumerated as determining the character and tendency of inflammatory products; namely, the degree or severity of the disease. For, as a general rule, the less the degree of inflammation is, the more is the product like that naturally formed in or by the part, till we descend to the border at which inflammation merges into an exaggerated normal process of secretion: as in hydroys articuli, hydrocele, coryza, &c.

These, it may be said, are only instances of secretions. But the instances of the so-called inflammatory hypertrophies may be regarded as parallel with those just referred to; for the analogies between secretion and nutrition are so numerous, the parallel between them is so close, that what can be shown of one may be very confidently assumed of the other. We may therefore believe, that, in the inflammation of any part, the product will, from the first, have a measure of the particular properties of the material employed in the normal nutrition of the part: that, as in the inflammation of a secreting organ, some of the secretion may be mingled with the product of the inflammation, so in that of any other part, some of the natural plasma, *i. e.*

some of the natural material that would be effused for the healthy nutrition of the part, may be mingled with the lymph. The measure of likeness to the natural structure acquired by the inflammatory product in its development, will thus bear an inverse proportion to the severity of the inflammation; because, the more the conditions of nutrition deviate from what is normal, the more will the material effused from the vessels deviate from the normal type. In severest cases of inflammation we may believe that unmixed lymph is produced, the conditions of the due nutrition of the part being wholly changed; but when the inflammation is not altogether dominant, its product will be not wholly contrary to the natural one, and will, from the first, tend to manifest in its development some characters correspondent with those of the natural formations in the part. Thence, onwards, this correspondence will increase as the new tissue is itself nourished: as scars improve, so do false membranes and the like become more and more similar to natural tissues.

To sum up, then, what may be concluded respecting the conditions that, in the first instance, may determine the adhesive or suppurative characters of an inflammatory exudation: they are, 1st. The state of the blood — its diathesis or crasis—the power of which is evident in that the same material may be exuded in many inflamed parts in the same person; in that this material may exhibit peculiar characters correspondent with those of the blood itself; and in that, in different persons, an inflammation excited in the same tissue, and by the same stimulus, will produce different forms of lymph, corresponding with differences of the blood. 2d. The seat of the inflammation, and the tissue or organ affected; of which the influence is shown by cases in which, with the same condition of blood, different forms of lymph are produced in different parts or organs. 3d. The

severity, and acute or chronic character, of the inflammatory process, according to which the product deviates more or less from the character of the natural secretion or blastematous effusion in the part.

The primitive character or tendency of any case of inflammation might be represented as the resultant of three forces issuing from these conditions.

The last product of inflammation of which I have to speak is *Mucus*.

Peculiar difficulties, owing to imperfect investigations of what normal mucus really is, beset this portion of our subject.

Normal mucus, so far as it has been examined, is a peculiar viscid, ropy, pellucid substance, which, of its own composition, has no corpuscles or organized particles. Such mucus is to be found in the nasal cavities of sheep and most large mammalia, and in the gall-bladder when its duct has been totally obstructed. In these parts, mucus may be found without corpuscles ; and probably there are other examples of such pure and unmixed mucus.

With all these, however, accidental mixtures commonly occur, of epithelial particles from the mucous membrane, and of corpuscles from the imbedded mucous follicles. And these particles vary according to the seat of the membrane, the fluid with which the mucus may be mixed, as gastric acid, intestinal alkali, &c., the time the mucus may lie before discharge, and other such conditions.

The first effect of a stimulation, within the normal limits, is to increase the secretion of the proper mucus, making it also more liquid ; to increase the quantity of the epithelium cast-off with the liquid ; and, often, to induce the premature desquamation of the epithelium, so that particles of it imperfectly formed may be found in the mucus.

Many of these immature epithelial particles have been named mucus-corpuscles or mucus-cells.

In an established inflammation of a mucous membrane, there appear, mixed with mucus, and with imperfect or degenerate epithelium, materials which closely resemble, if they are not identical with, the lymph-products of inflammation in other parts. I am, indeed, disposed to think that we should not draw a strong contrast between the inflammatory products of mucous membranes and those of serous membranes, and other parts, except in relation to the material with which, in the several cases, they are mixed. For, in certain inflammations of mucous membranes, we find fibrinous exudations; as in Hunter's experiment of injecting strong irritants into the vagina of asses;* they are found also, but less pure, in croup and bronchial polypus;† and I have seen them in the renal pelvis, ureters, and bladder in a case of calculus. In other cases, we find, either without fibrine, or mixed with minute soft flakes of it, corpuscles, which are, also, commonly called mucus-corpuscles, but which appear to differ from those in the lymph already described, only because of the peculiarly viscid fluid in which they lie. All appear to be, alike, lymph-corpuscles: but in the one case they lie in a serous, in the other in a mucous fluid, in which they appear clearer, more glistening, more perfectly pellucid, less plump, and are less acted on by water.

From these inflammatory products in mucus may be derived, by various degenerations of the fibrine, the flaky and molecular materials which commonly make morbid mucus look turbid and opaque; and by corresponding degenerations of the corpuscles, (*i. e.* of the lymph-corpuscles, not

* Works, vol. iii. p. 341. Museum of the College, Nos. 83, 84.

† See Henle, in his Zeitschrift, t. ii. p. 178.

of any normal cells or nuclei), the more frequent pus-cells, which make the transition to the complete pus formed on mucous membranes in active inflammation.

Such degenerations are more frequent in the products of inflamed mucous surfaces than are any forms of development. Development of fibrine, I suppose, never happens here ; but in the corpuscles some indications of it may be found, especially when the inflammation is very slight, as in the end of a bronchitis. In this case, among the corpuscles, many may be found enlarged, having distinct cell-walls and clear well-defined nuclei with nucleoli.

But among these there are usually many that present a peculiar pigmental degeneration. In the grey, smoke-coloured mucus, commonly expectorated at the close of bronchitis, the peculiar colour, though commonly ascribed to the mixture of inhaled carbon, is due to the abundance of cells containing more or less numerous black pigment-gra-

FIG. 33.



nules. Particles of carbon or soot may by chance be present, but they only trivially contribute to the colour : it depends on the number of these pigment-cells, to which it is easy to trace the transitions from the lymph- or mucus-corpuscles. The chief stages of transition are seen in that the cells enlarge to a diameter of about $\frac{1}{1500}$ th of an inch, become clearer, and acquire one or two clear oval nuclei ; but, at the same time, minute black granules, almost like those of melanotic cells, accumulate in them ; and these, increasing in number and clustering, may at length fill the whole cell,

while the nucleus disappears. Subsequently, the cell-wall may burst or dissolve, and the black granules be set free.

It can hardly be supposed that the black granules are in any way derived from inhaled carbon, although it seems that this kind of mucus is most abundant in those who are exposed to atmospheres laden with coal-smoke; for the colour is completely destroyed by immersing the mucus in nitric acid or solution of chlorine. The occurrence of such pigment-cells, being, I believe, peculiar to the mucus of the air-passages, may be connected with the general tendency of inflammatory products to imitate the properties of the natural products of the inflamed part; for they closely resemble the black pigment-cells from which the lungs and bronchial glands derive their black spots and streaks and other marks. And it may be added, that their peculiar abundance in the slightest forms of bronchitis, compared with their absence in acute cases, affords another example, that the likeness of the morbid to the natural product is inversely proportionate to the severity of the inflammation.

LECTURE XV.

DEVELOPMENTS OF LYMPH.

In the last lecture I considered part of the contrast between the processes of nutrition in the normal and in the inflammatory state, endeavouring to illustrate the nature of the materials exuded from the blood-vessels of inflamed parts. The contrast in this particular cannot, indeed, be accurately drawn : for we have, as yet, no certain knowledge of either the properties or the quantity of the material separated from the blood, for the ordinary nutrition of each part ; we have no normal standard wherewith to compare, in this respect, the processes of disease. It is evident that the exudation in an inflamed part is superabundant ; but its error in quality can be proved only by its diversity in various cases, and by the differences which it commonly presents in the rate and method of its development or degeneration. It is of these processes in the exuded lymph, and of the contrast between them and the normal maintenance of a part, that I propose next to speak.

The biography of the lymph-product comprises much of the most important part of the pathology of inflammation : and if it were required to point out what, since Hunter's time, has contributed most to the progress of general pathology, one could scarcely hesitate to name the full appreciation of the fact, that inflammatory lymph, and other

primary products of disease, have an independent life, and are, of their own nature, capable of appropriate development, degeneration, and disease. We may regard this as one of the best achievements of the observations which Schleiden and Schwann began to generalise; for, till it was clearly apprehended, the idea of a part being organizable meant scarcely more than that it admitted of being organized by the forces of the parts around it; that it could be built-up by the arteries, and modelled by the absorbents, as a material plastic, yet passive, in the hands of workmen. Hence was derived the erroneous direction of inquirers, which sought for blood-vessels as the essential characters of organic life in a part; and for their varieties of size, and number, and arrangement, as the measures of the ability and method of development.

Now, more truly, we may study the lymph, as having a life only so dependent on the blood and vessels as are all the tissues of the body—dependent on them as conditions of life, but not as sole arbiters of the method or direction of the vital transformations. And I venture to think, that the chief aim of our observations, in this part of the pathology of inflammation, should be to learn, now, the exact relation in which the several products of inflammation stand to certain primary forms, as developments or degenerations from them. The catalogue of various corpuscles is already swollen to an extent that is confusing to those who are familiar with them, and repulsive to those who would begin to study them. It would be an easy task to increase it, and it might have a seeming of accuracy to do so; but what we want, is such a history of the inflammatory lymph, that we may arrange the components of this catalogue as indicating so many progressive stages of development, degeneration, or disease, in the primary products of inflammation. An attempt to construct such a history is the more

advisable, for the sake of the illustration which it may afford to the history of normal structures. There are, as I have already said, no normal instances in which we can see the materials that are effused for the nutrition of parts ; but we may assume something concerning them and their progressive changes from the analogy of the materials that are more abundantly produced in inflammations.

I propose, then, to devote the present lecture to some general, and only a very general, account of the developments of lymph. But let me first state the sense in which the term development is here to be employed.

I have said (p. 5, and 101) that, in the generally accepted meaning of development, we have adopted an arbitrary standard of comparison, in the assumption that the nearest approach to organic perfection is in the human body, at the age of manhood. The assumption may be right on the whole ; and a less arbitrary definition of development would, probably, be less useful ; yet it may be observed, that in what we take for the period and standard of perfection, many parts that were once highly organized and active have passed away, as the thymus gland ; and some are, in certain respects, rather degenerated than developed, as the renal capsules and the bones. Development, in its highest sense, should imply not merely that a part becomes more fit for membership under the most perfect economy, but, also, that such fitness is acquired with greater complexity of chemical composition, or with greater evidence of formative or other organic power, or with greater difference from the structure or composition of lower beings. With none of these characters of development does such a process as that of ossification agree ; and, therefore, as I have said before, when we call it the development of bone from cartilage, it should be with the understanding that the

term is applicable only because bone is the proper material of the skeleton of the adult human body.

This distinction is important in the pathology of inflammation. In all true or complete development we may believe there is a larger expenditure of vital force than in any other organic act ; for all such development, too, the external conditions need to be the most complete, and the least interfered with ; such development is the highest achievement of the formative force, the highest instance of what might be understood as "increased action" in a part.

To speak, therefore, of the development of inflammatory products, when already the normal development of the body is completed, may seem to imply the exercise of unusual vital force ; the renewal, as it were, of the pristine embryonic vigour ; and the existence of conditions more favourable for nutrition than even those of health are. But we may be led to judge differently, if it should appear that most or all of the so-called developments of inflammatory products are instances in which the tissues, though they are formed into the likeness of such as exist in the perfect human frame, yet acquire characters of lower organization than those they had in their earliest state. It will appear that they are such ; and that however much the inflammatory products may become, by their changes, better suited for the general purposes of the economy, they are, in relation to their own condition, rather degenerated than developed. The changes that they undergo are, therefore, not always declaratory of a large expenditure of vital force ; they are not such as the term "sthenic," or "increased action," applied to the inflammatory process, would suggest ; not such as to imply that it is an exaggeration of any normal method of nutrition.

With this understanding, however, the changes I shall presently describe may be called developments of inflam-

matory lymph or exudation ; they are developments in the sense of being approximations to the likeness of the natural tissues of the adult human body.

In the last lecture I spoke, generally, of the conditions upon which depends the production of such inflammatory lymph as may be most apt for development. They are all such as favour the production of a lymph rich in fibrine, and that fibrine clear, homogeneous, elastic, tough, and filamentous. But even such lymph as this may altogether fail to be developed, or may be arrested in any stage of its development, and turned into the downward course of degeneration, unless favourable external conditions are present with it. For the development of lymph, of whatever form, nearly all those conditions are requisite which are necessary for the normal development of the proper constituents of the body. It needs, in general, the due supply of healthy and appropriate blood, the normal influence of the nervous force, and, for the highest and latest forms of development, the normal condition of the proper elements of the affected part.

Now, the existence of these conditions for the development of lymph implies a cessation of the inflammatory process, and a recovery from whatever originated or maintained the inflammation. So long as inflammation lasts, no high development of the exudation already formed will take place ; rather, fresh lymph will be continually exuded, hindering the due process of development, and hindering it the more, because, as the general health suffers through the continuance of the disease, so the lymph freshly formed will be less and less prone to organization. We may see this illustrated in bad cases of pleurisy. The layers of lymph next to the pleura are always more prone to organization than the later-formed layers that lie next the cavity ;

while within the cavity all the lymph may retain its fluid form, or may have degenerated into pus. So, more openly, we may see an illustration of the ill effects of abiding inflammation, in the healing of wounds by granulation. An inflammation, ensuing or continuing in the wound, hinders all development of granulation-cells, even though it may be too slight to hinder their formation, and may be favourable to the production of the ichor- and pus-cells. We may truly say, that the conditions most favourable to the abundant production of lymph are among the most unfavourable to its development, *i. e.* to its complete and higher organization.

Even when the inflammation has ceased, and fresh lymph is not formed, still, development is often prevented or retarded for want of some necessary condition. The blood-vessels, long dilated, may remain in a state of congestion, distended as if paralysed, and filled with slowly moving blood. In such a state of "passive congestion," so apt to follow more acute attacks, development will not happen in even well-disposed lymph. We have parallel facts in the tardy development of granulations on the legs, in the healing of ulcers; and how much this depends on the defective movement of the blood is well illustrated by a specimen* appropriate to an observation of Mr. Hunter's. It shows three ulcers of the integuments of a leg; they were all granulating, and all healing; but their progress in healing was inversely proportionate to the hinderances of the blood. The lowest of the three, that most distant from the heart, and of which the vessels were subject to the pressure of the highest column of blood, was least advanced in healing; while the uppermost of the three was most advanced, and was nearly cicatrized.

* Museum of the College, No. 26.

But let us suppose all the conditions for development provided ; what will now determine the direction or result of the process ? Into what tissues will the lymph be formed ? Two chief things will determine this : first, the general natural tendency of organizable lymph, produced in inflammation, is to form filamentous, *i. e.* fibro-cellular or fibrous tissue ; and, secondly, all lymph has some tendency to assume, sooner or later, the characters of the tissue in or near which it is seated, or in place of which it is formed.

The natural tendency of lymph to the construction of fibro-cellular or connective tissue, such as composes false membranes or adhesions, and many permanent thickenings and indurations of parts, is shown by the production of this tissue under all varieties of circumstances, and in nearly all parts ; even in parts which, naturally, contain little or none. Thus, it is found in the brain, and in glands, as in the testicle ; within joints, even where adhesions only pass from one articular cartilage to another ; in the adhesions and thickenings of the most diverse serous membranes ; in the thickenings of the most diverse mucous ones. And with all these, we have the corresponding facts in the healing of wounds. All granulations, springing from what surface they may, tend, at least in the first instance, to the formation of filamentous tissue, such as we see uniting all parts in a stump ; and a large proportion of subcutaneous injuries are repaired by similar tissue, whatever parts may have been divided. And, sometimes, we may find incomplete instances of this development where the lymph is not even in continuity with any tissue, but floats free ; as in ascites, or in effusions into joints.

But besides this general tendency, we may recognise in inflammatory lymph a disposition to assume characters belonging to the part in which it was produced ; so that, for instance, that about fibrous and ligamentous parts will

be developed into peculiarly tough fibrous tissue ; that about bone will become osseous ; that in the neighbourhood of epithelium will form for itself an epithelial covering ; and so on. I referred to this fact in the last lecture, and suggested that this tendency of the developed lymph, to conform to the characters of the parts around it, is probably due to the original and inherent quality of the lymph ; that the material formed in the inflammation of each part partakes, from the first, in the properties of the natural products of that part, and partakes of them in an inverse proportion to the severity of the inflammation ; because, the more the normal conditions of nutrition are deviated from, the more will the material produced be unlike the normal product. Besides, when the conditions are restored to the normal type, the organized product of inflammation will constantly approximate more and more to the characters of the parts among which it is placed, or with which it has acquired membership. As scars improve, *i. e.* gain, gradually, more of the characters of skin, so do false membranes, and the like structures, formed by the organization of inflammatory lymph, acquire, by their own nutrition and development, more nearly the characters of the parts with which they are connected. Thus false membranes in the serous cavities acquire a covering of epithelium exactly like that which covers the original serous membrane, and their tissue becomes perfectly fibro-cellular ; adhesions of the iris may become black, apparently from the production of pigment-cells like those of the uvea ; thus, too, in adhesions of the pleura, even when they are long and membranous, pigment may be formed as in the pulmonary pleura itself ; and thus many other inflammatory products are gradually perfected, till we may come to doubt whether they be of normal or of morbid origin, so complete is the return from the aberrant action.

I will endeavour, now, to describe more particularly the transitions to the several tissues that may be formed from inflammatory lymph. I need not, indeed, describe the minute changes of development; for, as the fibrinous and corpuscular varieties of lymph resemble very nearly the two forms of reparative material, so (as far as they are yet studied), their respective methods of development are equally similar. On these points, therefore, I may refer to former lectures (p. 182, 186, 208, 244, &c.); and, if it seem strange that disease should thus so closely imitate health, let it be repeated, that this process of development of the lymph is not disease. The lymph is, indeed, produced in inflammation, but it is developed in health, when all the natural conditions of nutrition are restored.

The instances are very numerous in which the inflammatory lymph, following its natural tendency, becomes fibro-cellular, or fibrous, tissue. The general forms which, in these instances, it assumes are (1) adhesions, where the new-formed tissue is between free surfaces, and unites them; (2) thickenings, where the formation is in the substance of membranes; (3) indurations, with or without contractions, where it is in the substance of organs; (4) opacities of certain parts that were transparent.

The best examples of the formation of fibro-cellular tissue from inflammatory lymph are in the adhesions, or false membranes, found after inflammation of serous or synovial membranes. In the former, especially, the lymph is apt, in such favourable conditions as I have specified, to be thus developed. In an acute peritonitis, or pleuritis, for instance, it is usually, in the first instance, deposited in layers of uncertain thickness on the opposed surfaces of the membrane. The condition of these layers is variable. The lymph is sometimes greyish, half-translucent, compact, and

laminated, consisting chiefly of fibrinous material, and peculiarly apt for development: in other cases, it is yellowish, opaque, soft, succulent, or almost creamy, having a great preponderance of corpuscles, and being less fit for development: and between these forms are many connecting varieties of appearance.

In the first instance, the connection of the lymph with the surface of the serous membrane is, usually, such that it may be cleanly stripped-off. Its free surface presents great varieties; it may be flocculent, or villous, reticular, perforated, or nearly smooth. Commonly, at first, the surfaces of the two layers (the visceral and parietal layers as they may be called, after the portions of the serous membrane on which they are severally placed) are separated by serous fluid exuded, in various quantity, with the lymph. But they may be, in parts, continuous, or connected by bands or columns; and, usually, when the inflammation ceases, and such a state of circulation is restored as is favourable to the organization of the lymph, the same state is equally adapted to the absorption of the superabundant fluid. In this case, the opposed surfaces of the two layers of lymph are gradually brought into contact with one another, and with portions of lymph which had floated in the fluid: and now, as their organization proceeds, they are all united; they become continuous, and form "adhesions" between the opposite surfaces of the serous membrane, whether these be the surfaces of adjacent organs, as the abdominal viscera, or of any organ and of the cavity enclosing it, as in the case of the testicle and tunica vaginalis.

The method, and the chief part of the plan, of the organization of lymph in these cases, are, I believe, similar to those described in the healing of wounds by primary or by secondary adhesion; and the general results are the same. Various as are the forms and other conditions of adhesions

and false membranes (depending as they do on the relative positions and mobilities of the parts that they connect), yet their structure, when complete, is, I believe, uniform. They consist of well-organized fibro-cellular or connective tissue, with which (perhaps only at a late period) elastic tissue may be mingled: they possess abundant blood-vessels, the chief of which are parallel to the direction of their filaments; and their free surfaces are covered with an epithelium like that of the membranes which they connect.

Fibro-cellular tissue is formed in adhesions of synovial membranes as well as of serous membranes; and, probably, in the same manner. In both cases, moreover, it is very usual for lymph to be exuded in and just beneath the membrane, as well as on its surface; and this infiltrated or interstitial lymph, becoming organized, produces thickening and opacity of the membrane. The coincident organization of the lymph, in both positions, is well shown in the frequent instances of white spots in the cardiac pericardium, with adhesions between the pericardial surfaces. Such white spots, when completely formed, consist of new fibro-cellular tissue, exactly like that of the adhesions. It is by similar interstitial exudation of lymph, and by its development into fibro-cellular tissue, that the frequent adhesions take place between parts which, though connected, should slide freely upon one another: such as adjacent tendons, &c. From this is derived a large share of the stiffness that remains about injured joints; the parts that should slide pliantly over them are fixed by the new-formed interstitial fibro-cellular tissue. So, too, are formed various morbid thickenings of parts: as of pieces of integument, capsules of joints, &c. But, in many of these cases, the lymph retains very long its rudimental structures, and is, perhaps, on this account, peculiarly apt to degenerate and permit absorption or the ulcerative process.

I know no better example, for microscopic examination of interstitially deposited lymph, than an indurated chancre : but I have never found one in which the lymph-cells had reached a further development than the elongated caudate form.

Fibrous Tissue, as the result of the development of lymph, is found when the exudation is interstitial in any fibrous tissue : as in ligaments, capsules of joints, and the like. The best examples of it are in the laminated and nodular thickenings of the capsule of the spleen, or the thickening and induration of the periosteum, or the capsule of the hip-joint in chronic rheumatic arthritis. In all these cases, the new material is derived from repeated, but not acute, inflammations ; therefore, probably, though excessive, it is not widely different from the normal material for nutrition : and, the conditions for nutrition being little disturbed, it is developed into the exact likeness of the original texture with which it is intermingled and confused.

As the fibro-cellular and fibrous tissues, formed from inflammatory lymph, become more perfectly organized, they are prone to contract : imitating the contraction already described in granulations and scars (p. 236). Hence, in part, the contraction of the wall of the chest after pleurisy, and the various displacements and deformities of organs that have become adherent to adjacent parts : hence, in part also, the contractions of inflamed organs, as of the liver in cirrhosis : hence, too, an addition to the rigidity of joints when the parts around them have been inflamed ; and hence, with yet greater mischief, the contractions of the thickened valves and tendinous cords of the heart.

Adipose Tissue may be formed, if not directly from inflammatory lymph, yet in the fibro-cellular tissue of completely organized adhesions. I think it is not often so

formed : but, lately, Dr. Kirkes found a lung of which all the anterior part was covered with well-organized false membrane ; and in part of this was a quantity of perfect adipose tissue, more than four ounces in weight.

Elastic Tissue is sometimes abundantly formed in the adhesions developed from inflammatory lymph. I have not seen it except in such as are completely organized : and I think it is, in this case, as in the formation of scars, a late production (see p. 188 and 238). I believe, also, with Virchow,* that its formation depends, in some measure, on the membrane that is inflamed ; pleural adhesions being most favourable to it. In these it is often abundant ; its principal, but always slender, filaments lying in the same general direction as those of the fibro-cellular tissue.

Epithelium I have already mentioned as covering the surfaces of well-formed adhesions. I know of no observations proving whether the epithelial cells are developed directly from the lymph, or are a later construction from materials derived from the blood of the adhesion's vessels : but it is not rare to find, in inflammation of serous membranes, recent lymph-cells presenting many characters indicative of development towards epithelium ; flattened and enlarged, and having circular or oval clear nuclei.

Bone is often formed from inflammatory lymph. It may appear as a late transformation of lymph that has been organized into perfect fibrous tissue ; as in the osseous plates that are sometimes found in the false membranes of

* Verhandl. der Phys.-Med. Gesellschaft in Würzburg, 1850, p. 142. He describes here a peculiar thorny or dentate structure often presented by the elastic filaments in old adhesions.

the pleura, or in the pericardium. In most of these, however, there is not true bone, but an amorphous deposit of earthy matter, which is imbedded in the fibrous tissue, or which (as Rokitansky holds) is the residue of the degenerated and partially absorbed tissue.

The proper condition for the transformation of lymph into bone is that in which the exudation takes place in an inflammation seated in the bone itself, or, else, in or near the periosteum. Such inflammations have been called "ossific;" and the Museum of the College, like every other, abounds with specimens of their various results.

There is a great lack of minute observations respecting both the characters of the lymph exuded in inflammations of bone or periosteum, and the methods of its ossification. Such as have been made, indicate, as might be expected, a close resemblance to the processes described in the repair of fractures* (p. 243, et seq.) The lymph produced in moderate inflammation, and therefore likely to ossify, is, at first, according to Rokitansky, a dark red exudation, like gelatine, which, being gradually decolorized, becomes white, and at the same time acquiring firmness, becomes like soft flexible cartilage, and then like ruddy succulent bone. But though it be like cartilage, I suspect that cartilage is very rarely, if ever, formed in inflammation of bone; for it seems to be formed in the repair of fractures only when the conditions are more favourable than they are likely to be in any inflammations. Probably the lymph is more or less developed towards the fibrous tissue when it ossifies; and, as in the repair of fractures, so here, we may believe that ossification may be postponed till the fibrous tissue is quite formed, or that it may ensue in the rudimental state of the

* Köstlin, Müller's Archiv, 1845, p. 60; Rokitansky, ii. p. 172; Virchow, in his Archiv, i. p. 135.

tissue, whether in a nucleated blastema, or in cells like those of granulations.

It would be hardly possible to explain, without illustrative specimens, all the various appearances of bone new-formed in or after inflammations. It may be produced in the very substance of compact bone, after the softening and expansion of the original tissue which occur in the earlier parts of the inflammatory process, and to which I shall have again to refer. Or, it may be produced in the medullary or cancellous tissue; and here, commonly, it appears as a gradual thickening of the minute cancellous lamellæ and fibres of bone, which, as they increase, gradually exclude the proper structures of the diploe or medulla, and finally coalesce into hard solid bone.

But, by far the most common seat of the formation of new bone, and that in which it is almost always found when it exists in either of the former situations, is on the surface, between bone and periosteum, or even in the periosteum itself. Here it forms the various growths to which the general term Osteophyte has been given. In a series of specimens of common inflammation of bone or periosteum, it is not difficult to trace the changes of construction of the new bone, by which, like that formed in a process of repair, it gradually approximates to conformity with the bone on which it grows.*

At first, it is, when dried, light and friable, with a close, filamentous, velvety texture, and a smooth surface, gradually rising from that of the surrounding healthy bone. As it increases in thickness it becomes longitudinally grooved, as

* Any large Museum will supply such specimens. Those in the College of Surgeons are minutely described in the Catalogue, vol. ii. p. 83, e. s., and vol. v. p. 43, e. s.: those at St. Bartholomew's may be studied through the Indices, p. 1 and 57. Even different parts of a single specimen will show much of what is described.

if lodging blood-vessels passing, through it, from the periosteum to the old bone. Then, as fresh formations of new bone take place, they assume the form of nodules and thick plates, laid over the longitudinal grooves, and leaving large apertures for the passage of blood-vessels. Such plates, like nearly all bone new-formed in disease, present, at first, a porous surface and a finely cancellous lung-like texture. But, gradually, in whatever form, the new bone tends to become harder and heavier; the apertures that made its surface porous gradually diminish till they are obliterated, and thus the new bone, while still cancellous within, acquires a compact external layer, and becomes more firmly united to the bone beneath it. The process of induration continuing, the new bone acquires throughout a hard compact texture: its outer surface, no longer porous, becomes nearly as smooth as that of the old bone; its colour also changes to that of the old bone; and, finally, the two unite so closely that the boundary line between them can hardly be discerned.

Such is the gradual assimilation of the inflammatory product to the characters of the normal structure from whose disease it issued: a process peculiarly worth studying in the bones, because in them, more than in any other tissue, the changes can be leisurely examined. Those which I have described occur in common inflammations: such, *e. g.* as follow injuries, or exist in the neighbourhood of necrosis, or ulceration, or foreign bodies. They are generally observed, also, in specific inflammations of bone: but, among these it is worth observing how characteristic of different diseases are certain formations of the new bone. The pustules of variola, or the vesicles of herpes, are scarcely more characteristic of those diseases, than are the hard nodules of cancellous bone, clustered about the articular borders of bones that have been the seat of chronic rheu-

matism ; or the porous, friable, dirty, and readily ulcerating thin layers formed on the shafts in syphilis.*

Cartilage, I have said, is probably not formed in inflammatory lymph in the process of its ossification. Neither does it appear to be formed in the more acute inflammations of articular cartilage : but, we must not exclude it from the possible developments of inflammatory products, while we remember the observations of Mr. W. Adams† respecting the enlargements of the ends of bones in chronic rheumatic arthritis. In these, which are marked by such formations of new bone, and such thickenings of fibrous tissue, as we constantly ascribe to inflammations, there is manifest increase of the articular cartilage, and a subsequent ossification both of that which is new-formed, and, more slowly, of that which normally covered the head of the bone. The early conditions of the increase of the cartilage are not traced : but that it depends on inflammation, rather than on true hypertrophy, is probable, both from the concurrent signs and results of inflammation, and from the new cartilage falling short of the perfect characters of the old ; for it has a fibrillated intercellular substance, and scattered nuclei, and is prone to ossification.

It remains that I should describe the adjunct structures of organized inflammatory lymph. But this may be briefly done, because the account of the formation of new blood-vessels in granulations and other reparative materials might, I believe, be transferred hither (from p. 215). The question is, indeed, often raised, as in the corresponding instance of granulations becoming vascular, whether the blood-

* As in Nos. 572, 628, and others, in the College Museum.

† Trans. of Pathol. Soc. of London, vol. iii. 1851.

vessels are formed entirely of the material of the lymph, and, as it were, by its own power of development, or whether they are outgrowths from adjacent natural or original vessels, which, as the expression is, shoot-out into the lymph.

I think it nearly certain, for the following reasons, that the lymph forms neither vessels nor blood, but receives those that are projected into it from the parts on or in which it is placed.

1. The direct observations supposed to prove that blood is formed in lymph are very liable to fallacy, through the facility with which blood may be accidentally mixed with the lymph, in consequence of hæmorrhage during life or after death, or in the preparation of the specimens. Where these sources of fallacy have been avoided, I have never seen anything suggestive of a transformation of lymph into blood.

2. The development of blood from tissue-cells is limited, naturally, to the earliest period of embryo-life, as if it needed the greatest amount of force for development; afterwards, blood is not formed except through a long process of elaboration, and with the aid of many organs. Its formation, therefore, in the mal-conditions of inflammation is very improbable.

3. In no specimen of inflammatory lymph have I seen appearances of transitions from lymph-cells to blood-cells, such as we may see in the lymph of the lymphatics, both before and after it is poured into the blood-vessels.

4. Neither in any lymph have I seen appearances of such stellate cells as the interstitial blood-vessels of the early embryo are formed from; nothing comparable with them has ever come into view.

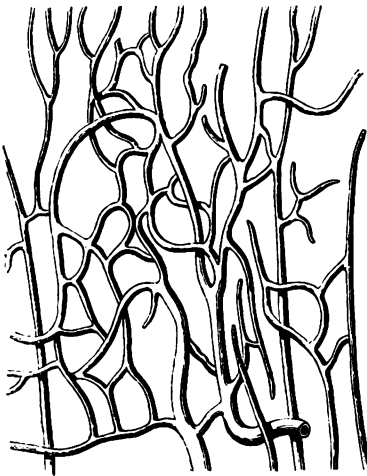
5. In the formation of vessels for granulations and the walls of chronic abscesses, all is favourable to the belief

that they grow-up from the blood-vessels of the adjacent parts ; and there are no structures to which the lymph bears so close analogy as it does to these, or to which it is so likely to be conformed in the production of its vessels.

On the whole, therefore, although direct observations are wanting, I think we may conclude that all the vessels of inflammatory lymph are formed by outgrowth from adjacent vessels, as in the process of repair, and that through these vessels, not by its own development, it derives its supply of blood.

In the first instance, the blood-vessels of lymph appear to be usually very numerous and thin-walled ; therefore easily bursting, or dilated by congestions during life, or in the

FIG. 34.



attempt to inject them after death. The College-collection contains an extremely beautiful specimen of soft recent lymph from the pericardium of a Cheetah, the vessels of which, injected by Mr. Quekett, appear as numerous and close-set as those of some of the more vascular mucous membranes. They present occasional slight and gradual dilatations, especially when they branch or anastomose.

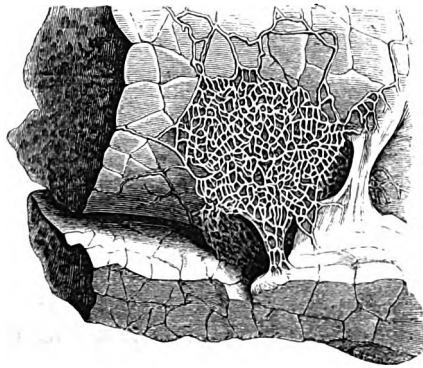
But after an uncertain time, as the lymph becomes more highly organized, so its vessels waste and diminish in number ; and while it acquires the proper structure of the fibro-cellular tissue, so it descends to the low degree of vascularity of that tissue. The vessels of false membranes, as represented here (fig. 34), from an instance in which they were

naturally injected with blood, are usually rather wide apart, long, slender, and cylindrical. In all these particulars they differ from those of more recently vascularised lymph; and their changes are, in these respects, parallel with those of the vessels of granulations during the gradual formation and perfecting of scars.

Perhaps the most perfect instance of the conformity with the natural tissues of the body to which the developed lymph can attain, is manifested in its acquiring a supply of lymphatic vessels. We owe the knowledge of the lymphatics of false membranes to the masterly skill of Professor Schroeder van der Kolk, whose preparations of them are described and represented by his pupil, Dr. de Lespinasse.*

In fig. 35, copied from one of his plates, beautiful networks of lymphatics, with their characteristic beaded forms and abundant anastomoses, are shown traversing adhesions extending between two lobes of a lung; while yet closer networks are seated in the thickened and opaque-white substance of the pleura, or of false membrane covering it, beneath the adhesions.

FIG. 35.



It seems to be in only the most perfect state, and when

* Spec. Anat. Path. de Vasis novis Pseudo-membranarum, 8vo. Daventriæ, 1842, figs. iii. iv. In another instance he injected lym-

blood-vessels have long existed, that lymphatics are formed in false membranes. In recent lymph Schroeder v. d. Kolk has never succeeded in injecting any; and we can only suppose that they are, like the blood-vessels, produced by out-growth from the lymphatics of the membrane with which they are connected.

Virchow* has twice seen nerve-fibres in adhesions. In one case, two fine nerve-fibres passed through an adhesion of the pleuræ; in the other, a single fibre extended into, but not through, an adhesion between the liver and diaphragm.

The time in which these complete developments of lymph may be accomplished must vary so much, according to the circumstances of the inflammation, that perhaps no reasonable estimate of it can be made. The experiments of Villermé and Dupuytren† upon dogs assign twenty-one days as the earliest time in which new vessels are formed; but I am disposed to agree with Dr. Hodgkin, that a shorter time is sufficient. On the other hand, I am sure that the supposition of their being formed in one or two days is incorrect. The principal case in support of this opinion is that recorded by Sir Everard Home; but the specimens preserved in the College Museum‡ show that he was deceived as to the true nature of the case. He says§

phatics in an adhesion between the liver and diaphragm. A similar injection of these in adhesions between an ovarian tumour and the small intestines is described by Lebert: *Traité des Maladies Cancereuses*, p. 40.

* Würzburg Verhandlungen, i. 144.

† Quoted by Dr. Hodgkin, in his *Lectures on the Morbid Anatomy of the Serous Membranes*, p. 42.

‡ Nos. 81 and 82 in the Pathological Museum.

§ In his *Dissertation on Pus*, p. 41. The whole case is given in the *College Catalogue*, vol. i. p. 37.

that he operated for strangulated hernia in a man, and found in the sac a portion of ileum, which was healthy, except in that its vessels were turgid with blood. The patient died twenty-nine hours after the operation; and on examination "several small portions of exuded coagulable lymph" were found adhering to the intestine that had been protruded. When the vessels of the intestine were injected, the injection passed into vessels in all these portions of supposed lymph, each "having a considerable artery..... and a returning vein." Sir Everard Home, therefore, concludes "that the whole operation of throwing out coagulable lymph, and supplying it with blood-vessels after it had become solid, was effected in less than twenty-four hours."

Now, one of these specimens was figured by Mr. Hunter,* "to show a small portion of coagulating lymph.....which is supplied with vessels;" but neither here, nor in his manuscript catalogue, does he allude to a probability of the vessels having been formed in twenty-four hours, although, had he believed it, he would scarcely have failed to record it.† An examination of the specimens shows that the small, shred-like portions of membrane, attached by little pedicles to the intestine, have not the appearance of recently coagulated lymph, but are fully organized, with traces of filaments and fat-cells. They are also very regularly disposed, at distances of from half an inch to an inch from each other, and are nearly all placed in two rows on each side of the intestine, about half an inch from the attachment of the mesentery, like very minute appendices epiploicæ, such as are occasionally met with on the coats of the small intestine. Whether they be such appendices

* Works; pl. xxi. fig. 2.

† In the Treatise on the Blood (Works, Vol. iii. p. 350) he speaks of nine days as a short time for the complete organization of adhesions.

or not, it is not in the highest degree improbable that they were formed after the operation ; especially since they are too minute and delicate to have prevented the intestine from exhibiting, when exposed in the sac, the natural polished appearance of its surface.

I am not aware of any other case adapted to prove the earliest period at which blood-vessels may be formed in lymph. Serous surfaces may, indeed, become adherent in twenty-four hours, but this does not imply vascularity of the lymph between them ; it is simply adhesion by the coaptation of the intermediate lymph.

LECTURE XVI.

DEGENERATIONS OF LYMPH.

HAVING given, in the last lecture, a general history of the chief developments of the lymph exuded in the inflammatory process, I propose, now, to tell a corresponding history of its degenerations; and herein to describe what appear to be the transitions, from the ordinary forms of lymph in its primary state, its fibrine and its corpuscles, to those many lower forms enumerated as molecular and granular matter; as pus-cells, granule-cells, inflammatory globules, and the rest.

I said that, for the development of lymph produced in inflammation, it is requisite that the inflammation shall have ceased, and the conditions of healthy nutrition be restored. In the failure of this event, if the inflammation continue, or the due conditions of nutrition be in any way suspended, then, instead of development, degeneration will occur, with more or less rapidity, according to the original character of the lymph. And this may happen in any of the stages of formation which I described in the last lecture: it may happen alike to the rudimental fibrine, or to the earliest lymph-cell, or to either, in any part of its progress to complete development.

The following appear to be the chief degenerations of the fibrinous part of lymph, or of the materials derived

from its earliest stages of development, whether in the purely fibrinous, or in any of the mixed, forms of lymph:—

1. It may wither; wasting, becoming firmer and drier, passing into a state which Rokitansky has designated *horny*. One sees the best examples of this change of fibrine in the vegetations on the valves of the heart, or in the large arteries, when they become yellow, stiff, elastic, and nearly transparent. The fibrine may, in this state, show no marks of development into tissue, but may have all the simplicity of structure of ordinary fibrine, being only drier and more compact. A nearly similar character is acquired when lymph is deposited over a lung which is extremely compressed in empyema, or in hydrothorax. The tough dry lymph that here forms the greyish layer over all the lung, is not always developed, though it may adhere firmly: it may be withered, wasted, and dried (as the lung itself may be), apparently in consequence of the compression.

2. The fibrine of lymph is subject to a degeneration which we may compare in many respects with fatty degeneration, or, more closely, with the changes by which lymph-corpuscles are transformed into those of pus, with which changes, indeed, this is commonly associated in the mixed forms of lymph. In the solid parts of effusions, that are found in the lower forms of inflammation, or in very unhealthy persons, the fibrine of the lymph is usually not clear and uniform and filamentous, but rather opaque or turbid, nebulous or dotted, presenting just such an appearance as marks the earliest stages of fatty degenerations in the muscular fibrils. In such lymph, also, one sees, not unfrequently, minute, shining, black-edged particles, which we may know to be drops of oil; while some general alteration in the composition of the fibrine is shown by its not being made transparent with acetic acid. In all such cases as these the fibrine is very soft, and easily broken: it is

devoid of all that toughness and elasticity which is the peculiar characteristic of well-formed fibrine; and by breaking it up, one may see the meaning of what one so often finds in the lowest forms of inflammatory exudation, such as occur in erysipelas and typhus; namely, films and fragments of molecular and dotted substance, floating in fluid that is made turbid by them, and by abundant minute molecules and granules and particles of oily matter. These represent the disintegration of fibrine that has degenerated after clotting, or has thus solidified in an imperfect coagulation. Of such changes, also, an excellent instance is presented in the softening and disintegration of clots within the heart, which Mr. Gulliver* first described. These, indeed, or any of the instances of the apparent suppuration within clots in the blood-vessels, might be studied for the illustration of the corresponding changes in inflammatory lymph; especially, in relation to the likeness which, in both cases, the degenerate fibrine bears to the molecular matter in the thinner and more turbid kinds of pus.

We have examples of numerous varieties of this degenerate and disintegrated fibrine exuded in inflammation. It is a principal constituent of most of what has been called "aplastic lymph," in inflammation of the serous membranes. Similar fibrine occurs, mingled with mucus, in the severer inflammations of the mucous membranes. And to the same source we may trace much of that molecular and granular matter which is usually mingled with all the less perfect forms of pus: *e. g.* with that formed in the suppuration of chronic inflammatory indurations; with the variously changed corpuscles of "scrofulous matter;" or with the granule-cells, and other corpuscles of pneumonia, and the like inflammations.

The general characters of the materials here described, and the coincident changes ensuing in the corpuscles that

* Medico-Chirurgical Transactions, vol. xxii. p. 136.

may be mingled with the fibrine, make it probable that the changes are of the nature of fatty degeneration occurring in the fibrinous lymph. But when, as I have said elsewhere (p. 234), we see how a large mass of inflamed hard substance will become fluid, as it suppurates, and this with scarcely any, if any, increase of bulk, we may believe that another change ensuing in the fibrine is that which I called liquefactive degeneration (p. 103). In such a swelling, we may be nearly sure there is coagulated fibrine, both from the general circumstances of the inflammation, and because neither corpuscles alone, nor fibrine in the liquid state, would give such hardness. The suppuration, therefore, if without increase of bulk, can hardly be explained, except on condition of the fibrine, which had solidified, becoming again liquid. The occasional liquefaction of clots out of the body* makes this more probable; but I am not sure that it can be proved by any more direct facts.

A point of some practical importance is connected with these forms of degeneration of lymph, whether affecting fibrine or corpuscles. When the fibrine has withered and become dry, it is probably put out of the capacity of being further developed, and is rendered passive for further harm or good, except by its mechanical effects. But the fatty and liquefactive degenerations may be yet more beneficial, in that they bring the lymph into a state favourable to its absorption, and, therefore, favourable to that which is termed the "resolution" of an inflammation in which lymph has been already formed. I suppose it may be considered as a general truth, that the elements of a tissue cannot be absorbed so long as they retain their healthy

* As in cases by Nasse and De la Harpe, quoted by Henle, in his *Zeitschrift*, B. ii. p. 169. See also Virchow on the same subject, in the same *Zeitschrift*, B. iv. Henle refers to this same liquefaction the changes that ensue in emitted semen.

state. There is no power of any absorbent vessels that can disintegrate or decompose a healthy portion of the body: for absorption, there must, in general, be not only an absorbing power, but also a previous or concurrent change,—as it were a consent, in the part to be absorbed; so that it may be reduced (or, rather, may reduce itself) into minutest particles, or may be dissolved. And this change is probably one of degeneration, not death, in the part; for dead matter is usually rather discharged from the body than absorbed.

Now such degeneration of the fibrine-products of inflammation as I have described, brings them into a state most favourable for absorption; indeed, one may see in lymph thus changed many things which, in regard to the fitness for absorption, make it parallel with chyle.* Of such absorption of fibrine we may find many instances. In rheumatic iritis we may believe the lymph to be fibrinous; but we see its complete absorption taking place; and the observations of Dr. Kirkes on the rarity of adhesions of the pericardium, in comparison with the frequency of pericarditis,* may be in the same manner explained. In rheumatic pericarditis we may be sure fibrine is exuded; and the observed friction-sound has, in some cases, proved its coagulation; yet in these cases, when death occurred months afterwards, scarce a trace of fibrine was found in the pericardium: it had been absorbed, and the degeneration I have been describing was probably the preparation for its absorption.

3. I am not aware of any direct proof of the calcareous degeneration ensuing in the fibrinous part of an inflam-

* See also the ingenious contrast of the progress of chyle and the regress of pus drawn by Gerber, in his *Allgem. Anatomie*, p. 49.

† *Medical Gazette*, April 1849.

matory exudation; but we have the strongest evidence from analogy for believing that this change may be a frequent one. For there are numerous instances of calcifications of fibrine within the vessels: as, *e. g.*, in the ordinary formation of phlebolithes from clots of blood, in the branching and irregular pieces of bone-like substance found in obliterated veins, and in the lumps and grains of substance like mortar imbedded in fibrinous deposits on the heart's valves. We can, therefore, hardly doubt that the fibrine, even before development, may take part in formations of earthy matter in inflammatory products; but the calcareous degeneration seems much more frequent in purulent fluids, and in the later developments of lymph.

4. Lastly, we have examples of the pigmental degenerations of fibrinous lymph in the various shades of grey and black which often pervade the lymph formed in peritonitis, and which are produced, not by staining or discoloration of the blood by intestinal gases, but, according to Rokitansky, by the incorporation of free pigment-granules.

Such appear to be the degenerations of the fibrine of inflammatory lymph: such at least are the changes in it which we may refer to defects in its power or conditions of nutrition, because they correspond with changes that may be traced in the gradual degenerations of old age. I need hardly say, that it is chiefly by such correspondence that we can interpret them; for when we find them, it is often beyond our power to tell, by direct observation, whether, or in what way, the conditions of nutrition were defective.

The corpuscular constituents of lymph, in any of their stages of development, may retrograde, and present dege-

nerations corresponding, and usually concurrent with those which I have just described.

1. Their withering is well seen in some forms of what is called scrofulous matter, such as occur in chronic and nearly stationary scrofulous enlargements of lymphatic glands. In the dull ochre-yellow-coloured, and half dry, material imbedded in such glands, may be found abundant cells, such as are sketched in fig. 36. They are collapsed, shrivelled, wrinkled, glistening, and altogether irregular in size and form. One might suppose them to be the remnants of pus dried-up, or the corpuscles of chronic tuberculous matter, if it were not that among them are some with nuclei shrivelled like themselves, and some elongated and attenuated, which are evidently such as withered after they had been developed into the form of fibro-cells; into which form it is certain that neither pus-corpuscles nor those of tubercle are ever changed.

FIG. 36.

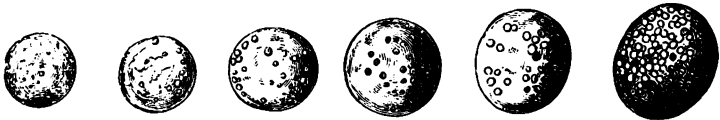


These are the best examples of withered lymph-corpuscles; but they may be also found in the pus of chronic abscesses, especially, of course, in that of such abscesses as ensue by suppuration of lymph-deposits like those just referred to. It may be hard, sometimes, to say whether corpuscles in these cases may not be pus-corpuscles shrivelled up: but on the whole, I am inclined to believe that the shrivelled corpuscles of the pus of chronic abscesses are usually derived from the lymph, in which, having withered, they had become incapable of further change.

2. The fatty degeneration of lymph-cells is shown in their transition into granule-cells.* We owe the first demonstration of this to the excellent observations of Reinhardt,† who has also shown how, by similar degenerations, corresponding forms of granule-cells may be derived from the primary cells of almost all other, both normal and abnormal, structures.‡

This method of degeneration appears peculiarly apt to occur in the inflammations of certain organs; as, especially, the lungs, brain, and spinal cord; but it may be found occasionally prevalent in the lymph of nearly all other parts, and in the granulations forming the walls of abscesses or of fistulæ. It may occur alike in the early forms of lymph-cells, and after they have already elongated and attenuated themselves, as for the formation of filaments, and after they have degenerated into pus-cells. The changes of transition, (as shown in fig. 37), are, briefly, these:—The lymph-cells, which may have at first quite normal characters, such as I have described (p. 333), present a gradual increase of shining, black-edged particles, like minute oil-drops, which accumulate in the cell-cavity, and increase in number, and some-

FIG. 37.



* The inflammatory globules of Gluge.

† Traube's Beiträge, B. ii. 217.

‡ Observations similar to part of those of Reinhardt were made independently by Dr. Andrew Clark. (Medical Gazette, vols. xlii. xliii.) See also Dr. Gairdner's description of the formation of granule-cells from epithelium-cells in pneumonia (Contributions to the Pathology of the Kidney, p. 20); and the list of references, p 147.

times in size also, till they nearly fill it. The fatty nature of these particles is proved by their solubility in ether : and their accumulation is attended with a gradual enlargement of the cell, which also usually assumes a more oval form. Moreover, while the fatty matter accumulates, the rest of the contents of the cell become very clear, so that all the interspaces between the particles are quite transparent ; and, coincidently with all these changes, the nucleus, if any had been formed, gradually fades and disappears, and the cell-wall becomes less and less distinct.

I need hardly say, that, in these particulars, the changes of the lymph-cells, (which may also occur when they have been already developed into the form of fibro-cells,) correspond exactly with those of the fatty degenerations observed in the cells of the liver or kidney, or in the fibres of the heart. There can be hardly a doubt of the nature of this process : and it presents an important parallel with the similar changes described in fibrine. For, we may observe, first, that where this degeneration is apt to occur in lymph, it is least likely to be developed. A proper induration and toughening of the lungs and brain, such as might happen through development of the products of inflammation, is extremely rare ; it is rarely seen, except in the scars by which the damages of disease are healed. And, besides, this degeneration is a step towards the absorption of the lymph ; for commonly we may trace yet later stages of degeneration in these granule-cells. They lose their cell-walls, and become mere masses of granules or fatty particles, held together for a time by some pellucid substance, but at last breaking up, and scattering their components in little clusters, or in separate granules.

Thus, if at no earlier period of their existence, or after no fewer changes, the lymph-corpuses may pass into a condition as favourable for absorption as is that of the

fibrine when similarly degenerate and broken up : and such as this, we may believe, is a part of the process by which is accomplished that "clearing up" of parts indurated and confused in inflammation, and, especially, that of the solidified lung, which is watched with so much interest in pneumonia.

3. Calcareous degenerations of the lymph-cells appear in cases, such as Henle* refers to, in which granule-cells are composed not wholly of fatty matter, but in part also of granules of earthy matter. In this combination they correspond with a common rule ; for the fatty and earthy degenerations are usually coincident : they are combined in the advanced stages of the degenerations of arteries, and may be said to have their normal coincidence in ossification.

4. Of the pigmental degeneration of lymph-cells there are, I suppose, examples in the black matter effused in peritonitis : but the best examples are in the cells in bronchial mucus, to which I have already referred (p. 348).

The most frequent degeneration of inflammatory lymph is into pus. It may ensue in nearly all the cases in which lymph is placed in conditions unfavourable to its development ; as in the persistence of inflammation, or in exposure to air, or in general defects of vital force. It affects alike the fibrinous and the corpuscular parts of lymph. For although we do not call any liquid "pus," unless it have the characteristic pus-corpuscles, yet the materials of degenerate fibrine are commonly mixed with these ; and indeed many of the varieties of the pus formed in inflammations owe their peculiarities to the coincident degenerations of the fibrine.

The facts proving the transformation of inflammatory lymph into pus correspond very nearly with those

* In his Zeitschrift, B. ii.

already cited (p. 231) concerning the similar relations of granulations to pus in the process of repair. But a few may be mentioned here :—

1. The fluid of such vesicles as those of herpes, is, in the first instance, a pure inflammatory lymph, containing corpuscles which might be taken as types of the lymph- or exudation-corpuscles, and which may be as easily distinguished from any cells of pus, as the cells of well-formed granulations may be. If we watch these vesicles, we see their contents not increased,—rather, by evaporation, they are diminished; but the lymph is converted into pus, and pus-cells are now where lymph-cells were. And the change may ensue very quickly: I think I have known it accomplished in twelve hours at the most.

2. In like manner, as I said before (p. 234), when we watch the progress of an abscess, we may find one day a circumscribed, hard, and quite solid mass, and in a few days later the solid mass is fluid, and this with little or no increase of bulk. Now the solidity and hardness are due to inflammatory lymph; the later fluid is pus; and the change is the conversion of lymph into pus.

3. As in common suppuration of a granulating wound, the granulation-cells appear to be convertible into pus-cells; superficial cells being detached in pus, while deeper ones are being developed into filaments; and as in worse-formed granulations, the cells are often by no characters, except by their forming a solid tissue, distinguishable from pus-cells; so, in an inflamed serous membrane, pus-cells may float in the fluid, such as cannot be distinguished from cells in the vascularized lymph that lines the cavity. In the fluid exudation, and in that which is solid, the same forms may be found; though, by comparison, we may be able to trace that in the former none of the cells were being developed, and many were proceeding beyond the degeneration to which any had attained in the latter.

3. One may see the same conversion of inflammatory lymph into pus thus illustrated. An amputation through the thigh was performed when all the parts divided were infiltrated with lymph, effused in connection with acute traumatic inflammation of the knee-joint. Next day pus flowed freely from the wound. Now, in amputation through healthy tissues, free suppuration does not appear till after three or four days: the pus here seen must have been formed by the conversion of the inflammatory lymph previously infiltrated in the divided tissues.* Similar facts may be less strikingly observed in any wound.

From these and the like facts we have an almost exact parallel, in their relations to pus, between the material for repair by granulations and that exuded in the inflammatory process; and between, if they may be so called, the reparative and the inflammatory suppurations. And in some of the facts we may trace a transition from the one process to the other. In the formation of an acute abscess, for example, inflammatory lymph is transformed into pus; then the pus, say, is discharged; the signs of inflammation cease; the process of repair is established, and reparative granulations line the abscess-cavity in the place of, or formed by, the peripheral layer of the lymph. Now, pus continues to be formed: but this pus is derived, not from inflammatory lymph, but from granulation-substance. So, also, when an inflamed part is cut, the first pus is from lymph: the latter pus, when repair is in progress, is from

* These facts, while they prove that the pus-cells are commonly the result of degeneration of lymph-cells, may also serve to show that the question often asked, whether pus-cells are ever an original or primary product of inflammation, cannot be precisely answered. We cannot always discern a preliminary lymph-stage; but neither can we always distinguish lymph-cells from pus-cells, whether in serous fluid or in mucus, nor can we say in how very brief a time the transformation from the one to the other may be accomplished.

granulation-substance. In both cases, alike, the pus manifests itself as a rudimental substance ill-developed or degenerated (see p. 233); and the transition from the one condition to the other is an evidence of the impossibility of exactly defining between the inflammatory and the reparative processes, unless we can see their design and end.

Much, therefore, of what was said respecting suppuration in connection with repair, might be repeated here. But, avoiding this, let me only point out the principal methods in which inflammatory suppuration ensues, and the relation of the pus in each to the previous or coincident inflammatory product. In this last respect, the suppuration of disease differs importantly from that of the reparative process, in that the degeneration may take place in any of the different varieties of lymph, and that, according to the primary character of the lymph, there may be traced (though as yet too obscurely) different appearances of the pus.*

The methods of such suppuration may be named the circumscribed, the diffuse, and the superficial. The first may be exemplified by the formation of an abscess or a pustule; the second by phlegmonous erysipelas, or purulent infiltration of any organ; the third by purulent ophthalmia, or gonorrhœa: and in these and the like instances we may often, at the close of the disease, watch the transition from the suppuration that depends on the inflammatory process, to that which is coincident with repair.

In circumscribed suppuration, which has its most usual seat in the cellular tissue, we can generally observe the previous signs of inflammation, and of an exudation of lymph in a certain area of the tissue. The exudation is inter-

* See especially Rokitansky: *Pathol. Anat.* B. i. p. 210.

stitial, or by infiltration ; and, probably, in most acute abscesses, is of a mixed kind, containing both fibrine, which may solidify, and a liquid material of which corpuscles may form themselves. The proper elements of the tissue are separated or expanded by the lymph thus inserted among them ; and the inflamed part derives from it much of its swelling, and much of its hardness while the fibrinous part of the lymph is solid. Generally, such a swelling is at first, comparatively, ill-defined ; and if it be near the skin, the visible inflammatory redness very gradually fades-out at its borders, where, in the deeper tissue, we may believe, the exudation is gradually less abundant. But, in time, the swelling usually becomes more defined ; the inflammation, as it were, concentrates itself, and appears more completely circumscribed. Now the lymph, in such a case, may be absorbed, or may be developed so as to form a long-continuing thickening and induration of the part : but, in the case I am supposing, it is transformed into pus ; its corpuscles changing their characters in the manner already described, (p. 232) and its previously solidified part becoming liquid. The change almost always begins at or near the centre of the lymph, where, we may believe, the conditions of nutrition are most impaired. It may extend from a single point, or from many which subsequently coalesce. In either case, the central collection of matter remains surrounded by a border or wall of indurated tissue, in which the infiltrated lymph is not transformed into pus, but, rather, tends to be more highly organized. This border or peripheral layer of lymph now forms the wall, as it is called, of the abscess, and the finger may detect, as the best sign of abscess, a soft or fluctuating swelling with a firm or hard border. The expressions commonly used are, that the suppurative inflammation has taken place in the centre of the swelling, and that its effects are bounded by the

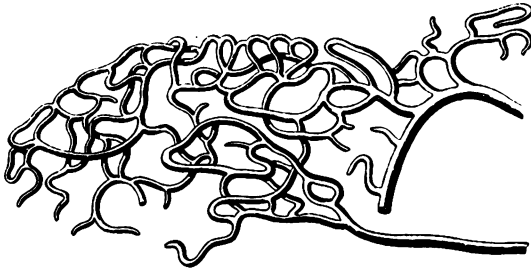
adhesive inflammation: it might be said, with the same meaning, but perhaps more clearly, that, of a certain quantity of lymph deposited in the original area of the inflammation, the central portions have degenerated into pus, and the peripheral have been maintained or more highly developed: and, probably, we may add in explanation, the difference has depended on the degrees in which the conditions of nutrition have been interfered with in the places in which the two portions have been seated. In the central parts of an inflammatory swelling, the circulation, if not wholly arrested, must be less free than in the peripheral; the blood, moving very slowly, or stagnant, must lose more of its fitness for nutrition; the tissues themselves are more remote from the means of maintenance by imbibition: in these parts, therefore, degeneration, if not death, ensues; while, in the peripheral parts, maintenance, or even development, is in progress.*

Now, in the ordinary course of such an abscess, the purulent matter is discharged. (I shall speak in the next lecture of the manner in which this takes place, as well as of the changes that ensue in the tissues among whose elements the lymph is infiltrated.) On the interior of its wall, especially if its course have been very acute, we may find a thin, opaque, yellowish-white layer, easily to be detached,

* Expressions are sometimes used which imply that the wall of the abscess is formed by an adhesive inflammation following, and purposely consequent on, the suppurative. This certainly happens, if ever, very rarely: it only seems to take place when suppuration is accompanied by extending inflammation. In such a case, that which is to-day the indurated abscess-wall, may, to-morrow, have become pus; and new inflammatory products, deposited around it during its degeneration, will form then, the boundary of the enlarged abscess. It may be, indeed, that the lymph deposited at the centre of the inflammatory process is, naturally, less organizable than that at the periphery; but this is not proved.

flaky, or grumous. It is usually formed of lymph-cells or pus-cells imbedded in flakes of soft fibrinous substance. It has been made to seem more important than it is, by being called by some a "pyogenic membrane," and by its being supposed that it is the work of the cells to secrete the pus. But the existence of such a layer is far from constant in abscesses; it is, often, a sign of the imperfect organization of the abscess-wall; its materials are probably oftener detached and mingled with the pus than they are vascularized; and no such layer is found when free suppuration continues in an open abscess. A more normal course is observed when the progress of suppuration has been slower. In this case, the wall of the abscess becomes more highly organized after the discharge of the contents; the circulation being restored in the infiltrated tissues of which the wall is formed, the lymph is developed, or at least, if I may so speak, more highly vivified, and its cells, or new ones formed next to the abscess-cavity, are constructed into granulations, and are supplied with blood-vessels, like those on the surface of a healing suppurating wound. Such vessels are represented in this sketch.

FIG. 38.



With, or soon after, the evacuation of the purulent matter, the disease on which the abscess depended may cease: and, if this be so, the later progress of the case is

a process of healing which may, in every essential character, be likened to the healing of a wound by granulation. There is the same gradual development of the lymph-cells, or, as they might now be called, the granulation-cells of the walls of the abscess,—first of the deeper, and then of the more superficial cells. The same contraction, also, attends this process, and serves to diminish the area of the cavity, and to bring its walls more nearly into correspondence and proximity with the external opening, till, coming into contact, the opposite surfaces of granulations may unite, as in healing by secondary adhesion; or till, as the edges of the opening are retracted and depressed, and the floor of the abscess is raised, they are brought nearly to a level, and heal as a single granulating surface.

Such an abscess as I have described is often called acute or phlegmonous, in contradistinction from those collections of pus which, being formed without the observed signs of inflammation, and, generally, slowly, are named cold or chronic abscesses. Observations are wanting, I believe, which might show how far the chronic abscesses differ from such as I have described in their early condition; and, especially, whether there be first a circumscribed infiltration of lymph, of which part degenerates and the rest is developed. It is probable the phenomena are essentially the same; for instances of all possible gradations between the two forms may be observed; and, in the complete state of the chronic abscess, the structures are not widely different from those of the acute. The abscess-wall is usually firmer, more defined, so that it can often be dissected entire from the adjacent parts, and has its tissue more developed, and more like those of a membranous cyst: the lining is generally less vascular, smoother, and less distinctly granulated; the contents are usually thin and serous, and indicate not only that the material of which

they are composed was peculiarly unapt to be organized, but that, even after its transformation into pus, further degenerations ensued in it.

The diffuse suppuration, as I have said, may be exemplified by phlegmonous erysipelas. Here, with well-marked phenomena of inflammation, lymph is exuded through a wide extent of the subcutaneous cellular tissue, and, from first to last, the boundaries of the exudation are ill-defined: the suppuration is, indeed, most certain and complete at the centre, or where the inflammation began; but it may be nearly co-extensive with the exudation, and most rarely presents a well-defined boundary-wall, as in abscess. The lymph, in its primary character, is mixed; its fibrinous constituent is evident in the coagulation that ensues when it is let out (see p. 326), and, usually, in the abundant molecular matter in the pus. The exudation is even more distinctly interstitial than in an abscess; the tissue is thoroughly infiltrated with it, and is, comparatively, little expanded: and when suppuration has ensued, and we cut into the inflamed parts, the pus often flows out slowly, or even remains entangled in the tissue. The same condition is, often, yet more plain in the purulent infiltrations of such organs as the lung; their tissues are completely soaked with pus. The infiltrated tissues themselves are usually softened, not only by the mixture of the unorganized inflammatory matter, but through their own degeneration; and, very generally, large portions of them perish, and are found as sloughs infiltrated with pus.

In regard to their structural changes, there may appear little difference between this condition and that of acute abscess, except in the contrast of the one being less, the other more circumscribed. But in regard to the materials exuded, they are, probably, in the phlegmonous erysipelas,

much less naturally apt for organization than in the abscess. The central suppuration of an abscess, while the lymph around is organizing, implies that the degeneration depends much on the local defect of the conditions of nutrition : the diffuse suppuration seems due, in a larger measure, to original defect of the lymph ; and these differences correspond with those of the constitutional states attending the two diseases.

After the discharge of the pus, the healing of the diffuse suppuration is, in all essential respects, similar to that of the abscess ; but the methods of discharge are much more diverse. Sometimes, after extensive sloughing of the skin, wide-spread suppurating cavities are exposed, which then granulate and heal like wide-open wounds ; sometimes, numerous isolated suppurations ensue, whence the pus is discharged as from so many small ill-defined abscesses, in each of which the ordinary healing occurs, while the intermediate parts are indurated by the imperfect organization of the lymph ; sometimes, from a comparatively small opening, large sloughs are discharged, and then the boundaries of the subcutaneous cavities which they leave granulate, and healing takes place as by secondary adhesion.

The superficial inflammatory suppuration is such as we observe in gonorrhœa, and in purulent ophthalmia, and generally in the inflammations of mucous membranes. Here, the material exuded is least apt for organization, partly because of the situation in which it is produced, and partly through its own natural condition ; for though exudation takes place, in these cases, within the tissue of the inflamed membrane, as well as on its surface, yet the amount of thickening, or other structural change, that takes place is slight, if we compare it with the changes that, in the same duration and severity of inflammation,

would ensue in fibro-cellular tissue, or in serous membranes.

I have already spoken of the changes of mucus in the inflammatory process, and of the mixture of lymph that then occurs. The lymph is chiefly of the kind that forms corpuscles; and there is no instance in which the rapidity of formation of such corpuscles, and of their change into the characters of pus-cells, can be watched. It is, indeed, chiefly, in some of these cases of inflamed mucous membranes, that one may doubt whether it is reasonable to speak of the formation of lymph-cells as preceding that of pus; for, especially in the more acute inflammations, the characters of pus-cells seem to be acquired in the very beginning of organization of the exuded liquid. And this character of the cells is often retained, even after the product of the inflamed membrane has regained, to the naked eye, a more mucous appearance; for here (unless ulceration of the membrane have ensued) the process of recovery from inflammatory suppuration is not through such healing by granulation, as in the former cases, but by a gradual return to the secretion of a more normal material; and in this recovery, the inflammatory exudation becoming gradually less, the corpuscles that are formed, though they may assume the characters of pus-cells, are not sufficient to give a purulent character to the liquid.*

* The question of the diagnosis between mucus and pus should, perhaps, be here referred to. Between normal mucus and pus there can be no confusion (see p. 346). Between the mucus and the pus of an inflamed mucous membrane, the difference corresponds, in some measure, with that between lymph and pus; depending, first, on the proportion in which the inflammatory material is mingled with the proper constituents of the mucus, and, secondly, on the degree in which the former tends to assume the purulent characters. In other words, the diagnosis required is not, strictly speaking, so much between mucus

The superficial suppuration from inflamed mucous membranes is closely related to that from an ulcerated surface. I think, indeed, that an inflamed mucous membrane may yield purulent matter, even though it remain covered with an epithelium. I believe this happens in gonorrhœa and in purulent ophthalmia: the vascular tissues, in these affections, appear still to have epithelium on them, though perhaps it is too thin and immature, and is reduced to a condition analogous to that of the thin and moist glistening epidermis on the inflamed "weeping" leg. But observations are wanting on this point. The transition to the suppuration from an ulcerated surface takes place when the epithelium is wholly removed from a mucous membrane. This constitutes its abrasion or excoriation; in the next stage, the surface of the membrane itself is cast off, and this is its ulceration or erosion.*

Such are the several chief methods of inflammatory suppuration, and the relations of the pus to other products of the disease. In all the cases, a point of contrast between pus and any form of lymph is to be found in its complete incapacity for organization.

When once formed, the pus-cells, if they are retained

and pus, as between the lymph and pus which are, in different cases, mingled with the mucus of inflamed membranes. And this diagnosis is one which it is easy to make, in many cases, according to such characters of the corpuscles as have been already described; but, in other cases, it is impossible, if it so chance that the materials are in the transition-stage from lymph to pus.

* The whole of the subjects of this paragraph are clearly and very fully illustrated, in relation to the affections of the mucous membrane of the uterus and vagina, by Drs. Tyler Smith and Hassall, in a paper which will appear in the 35th vol. of the *Medico-Chirurgical Transactions*, and of which an abstract is in the *Lancet* and the *Medical Times* of July 31, 1852.

within the body, have no course but to degenerate further ; it is characteristic of their being already degenerate, that they can neither increase nor develop themselves. Various corpuscles found in pus, besides those I have already mentioned, may find their interpretation in these degenerations ; for the pus-cells are prone to all the degenerations that I described as occurring in the lymph-cells.

They may wither, as in the scabbing of pustular eruptions, or in long-retained and half-dried strumous abscesses.

Or, they may be broken-up, whether before or after passing into the fatty degeneration, which is one of their most common changes, and in which they are transformed into granule-cells. It is this breaking-up into minute particles which, probably, precedes the final absorption of pus.

Or, lastly, both the cells and the fluid part of the pus may alike yield fatty and calcareous matter, and this may either remain diffused in fluid, or may dry into a firm mortar-like substance.

It is to such degenerations as these, in various degrees and combinations, and variously modified by circumstances, that we must ascribe the diverse appearances of the contents of chronic abscesses, and of the substances that remain when abscesses close without complete final discharge of their contents. In such abscesses we may find mixtures of pus-cells, granule-cells, and molecular matter, diffused in more or less liquid ; or pus-cells, half-dried, shrivelled, and showing traces of their divided nuclei ; or, all cells may be broken up, and their débris may be found mingled with minute oily particles, which appear in such cases to be always increasing ; or, with these may be abundant crystals of cholesterine ; or, such crystals may predominate over all other solid contents. In yet other chronic abscesses (though, still, without our being able to tell why the pus

should degenerate in these rather than in the foregoing methods), we find molecules of carbonate and phosphate of lime, mixed with fat-molecules and crystals, which are diffused in an opaque-white fluid, and look like a deposit from lime-water, or like white oil-paint; and as these contents dry, in the healing of the abscess, so are formed the mortar-like deposits and the hard concretions, such as are found in the substance of lymphatic glands, or other organs that have been the seats of chronic abscesses.

Time and patience would fail in an attempt to describe all the varieties of material that may thus issue from the transformations of pus. What I have enumerated are the principal or typical forms with which, I believe, nearly all others may be classed; though not without consideration of the various substances that may be accidentally mixed with the pus; as blood, *débris* of tissues, &c.

In conclusion of this part of the subject,—of this biography of inflammatory lymph,—a few words must be added respecting the degenerations and diseases which may occur after it is completely organized. The degenerations to which I have now so often referred, may be observed in fully-formed adhesions, or in the corresponding organized tissues in the substance of organs.

Of the wasting of adhesions we often see instances in the pericardium, where films of false membrane are attached to one layer of the membrane, while the opposed portion of the other layer is only thickened and opaque. A more remarkable instance is presented in a case by Bichat, in which a man made twelve or fifteen attempts at suicide, at distant periods, by stabbing his abdomen. In the situations of the more recent wounds, the intestines adhered to the walls of the abdomen; in those of the older wounds, the older

adhesions were reduced to narrow bands, or were divided and hung in shreds.

To similar wasting atrophy we may refer the extreme thinning and perforation of false membranes, by which, as Virchow* has well described, they became fenestrated like wasted omentum.

Of fatty degeneration I have seen no good examples in adhesions or similar inflammatory products, but of calcareous degenerations, or of such as present a combination of fatty and earthy matter, museums present abundant specimens. Among these are most of the plates of bone-like substances imbedded in adhesions of the pleura, in thickened and opaque portions of the cardiac pericardium, in the tunica vaginalis in old hydroceles, in the thickened and nodulated capsule of the spleen, in the similarly altered mitral and aortic valves. So, too, many of the so-called ossifications of muscles and ligaments are examples of calcareous degeneration of fibrous tissue, formed in consequence of inflammation of these parts, and imbedded, in masses of fibrous-looking bands, within their substance. In some of these cases, indeed, there may be an approximation to the characters of true bone; but in nearly all, the earthy matter is deposited in an amorphous form, and seems to take the place of the former substance, as if, according to Rokitansky, it were a residue of the transformation of the more organized tissue, whose soluble parts have been, after decomposition, absorbed.†

Pigmental degeneration of adhesions may be seen, sometimes, in those of the pleura, in which black spots appear like the pigment-marks of the lungs and bronchial glands.‡

* Würzburg Verhandlungen, B. i. p. 141.

† Numerous specimens of the calcareous degeneration of adhesions are in the College-Museum; *e. g.* Nos. 103, 1493, 1494, 1516, &c.

‡ As in No. 96 in the College-Museum.

Adhesions of the iris, also, may become quite black, by the formation of pigment like that of the uvea.

Lastly, it must be counted among the signs of its attainment of complete membership in the economy, that the organized product of inflammation is liable to the same diseases as the parts among which it is placed; that it reacts like them under irritation; is, like them, affected by morbid materials conveyed to it in the blood; and, like them, may be the seat of growth of new and morbid organisms. No more complete proof of correspondence with the rest of the body could be afforded than this fact presents; for it shows that a morbid material in the blood, minute as is the test which it applies, finds in the product of inflammation the same qualities as in the older tissue to which it has peculiar affinity.

The subject, however, of the diseases to which these substances, themselves the products of disease, are liable, has been little studied. I can only enumerate the chief of them.

Lymph, while it is being highly organized, is often the seat of hæmorrhage; its delicate new-formed vessels bursting, under some external violence, or some increased interior pressure, and shedding blood. Such are most of the instances of hæmorrhagic pericarditis, and other hæmorrhages into inflamed serous sacs.

Even more frequently, the lymph, when organized, becomes itself the seat of fresh inflammation. Thus, in the serous membranes, we may find adhesions, in the substance or interstices of which recent lymph or pus is deposited;* or, in other cases, adhesions, or the thickenings and opa-

* As in No. 1512 in the College Museum. The specimen has some historic interest. It is one of those by which, in 1808, attention was first drawn, by Sir David Dundas, to the connection between acute rheumatism and disease of the heart.

cities of parts, become highly vascular and swollen. It is, indeed, very probable that, in many of the instances of the recurring inflammations that we watch in joints, or bones, or other parts, the seat of the disease is, after the first attack, as much in the organized product of the former disease as in the original tissue.

I suppose, also, that to such inflammations of organized inflammatory products, we may ascribe many of the occasional aggravations of chronic inflammations in organs; the renewed pains and swellings of ankylosed joints, of syphilitic nodes, and the like; which are so apt to occur on exposure to cold, or in any otherwise trivial disturbances of the economy. In such cases we may believe that the former seat of disease becomes more inflamed, and that with it are involved the organized products of its previous inflammations. And in such cases there are, perhaps, none of the effects of inflammation which may not ensue in the newly organized parts: evidently, they may be softened, or thickened and indurated, and made more firmly adherent: or they may be involved in ulceration, or may slough with the older tissues among which they are placed.

Lastly, the products of inflammation may be the seats of the morbid deposits of specific diseases. In their rudimentary state they may incorporate the specific virus of inoculable diseases; such as primary syphilis, variola, and the rest; and, when fully organized, they may be the seat of cancer and tubercle.

LECTURE XVII.

CHANGES PRODUCED BY INFLAMMATION IN THE TISSUES OF
THE AFFECTED PART.

THE account of the results of inflammation, in the tissues of the part in which it has its seat, will include the chief among those destructive processes which, I said in a former lecture (p. 325), may be reckoned as a second division in the inflammatory changes of the nutritive process. For I believe that all the effects of inflammation are injurious, if not destructive, to the proper tissues of the part in which it is seated. All the changes I shall have to describe are characteristic of defect of the normal nutrition in the parts: they are examples either of local death, or of some of the varieties of degeneration, modified and peculiarly accelerated by the circumstances in which they occur. The degenerations are observed, most evidently, in the processes of softening and absorption of inflamed parts. These I shall, first, endeavour to illustrate; and then, after some account of the minute changes that are associated with them, I will describe the process of ulceration; reserving for another lecture the account of the death of parts that may occur in inflammation.

Let me, however, at once state that the changes in the proper tissues of an inflamed part are, generally, of twofold origin. (1.) They are due to the natural degeneration of the tissue. That degeneration, which would be progressive in the healthy state, but which would then be unobserved, being constantly repaired, is still progressive in the in-

flamed state of the part, and is the more rapid because of the suspension or impairment of the proper conditions of nutrition. (2.) They are due, also, to the penetration of the products of inflammation into the very substance of the affected tissue; not merely into the interstices of its elemental structures, but into those structures themselves. These two methods of change are not essentially connected; but they are generally, in various proportions, coincident and mutually influential; and when concurring it is hardly possible to assign to each its share in the result to which they lead.

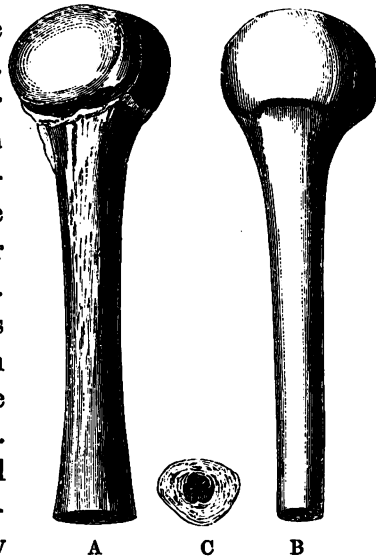
One of the most common effects of inflammation in an organ is a more or less speedy *softening* of its substance: and this is due not only to infiltration of it with fluid, but to a proper loss of consistency, a change approaching to liquefaction, or to disintegration, of which, indeed, it is often the first stage. Of such softening, some of the best examples are in the true inflammatory softening of the brain and spinal cord, in which the softened part is usually found to consist of broken-up nervous substance, together with more or less abundant granular products of inflammation. Such softening also may be found in the lungs: the peculiar brittleness and rottenness of texture, which exists with the other characters of hepatization, are evidently due to changes in the proper tissue, more than to incorporation of the products of inflammation. In staphyloma of the cornea, similar softening ensues in connection with the opacity and other changes of appearance. But, perhaps, the most striking instance of softening in inflammation (and it is the more so because the softening probably precedes the other evident signs of inflammation*) is to be

* See Küss, as quoted by Virchow, in his *Archiv*, i. p. 121.

found in bones. One may generally notice that an acutely inflamed bone is soft, so that a knife will easily penetrate it. Thus it may be found in the phalanges of the fingers when they partake in deep-seated inflammation, and thus, sometimes, in the neighbourhood of diseased joints. The change depends partly on an absorption of the earthy matter of the bone, this constituent being removed more quickly, and in greater proportion, than the animal matter;* but the entire material of the bone is softened.

The softening of bones may permit peculiar subsequent changes, especially their swelling and expansion. Thus, in a remarkable case communicated by Mr. Arnott to Mr. Stanley, after excision of the bones of an elbow-joint, inflammation ensued in the shaft of the humerus, and after four months the patient died. The end of the humerus was full-red, and swollen, with expansion or separation of the layers of its walls (fig. 39). And the case showed well the coincidence of absorption and of enlargement by expansion; for though the inflamed humerus was thus

FIG. 39.†

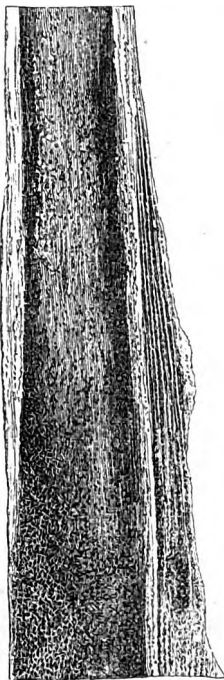


* Gendrin, *Hist. des Inflammations*, i. p. 383.

† A, the inflamed humerus. The swelling of its lower part is shown by contrast with that of the corresponding part of the healthy humerus B. The separation of laminae is shown in C: all the figures are reduced one-half. From Mr. Stanley's *Illustrations*, pl. i. figs. 4, 5, 6.

enlarged, and contained more blood than the healthy one, "yet it was found not to weigh so much by half."

Similar expansions of bone, with all the characters of inflammation, and such as could not have happened without previous softening of the tissues, form part of the many swollen and enlarged bones which are common in all museums.* Doubtless, in many of these cases, the disease has been of very slow progress, and the separation of the several layers of the compact bone, which the specimens display, must be ascribed to their gradually altered form, as they have grown about the enlarging blood-vessels and inter-laminar inflammatory deposits. But, in other cases, the expansion has in all probability been more rapid, the softened bone yielding and extending, as the naturally softer tissues do, in an inflammatory swelling.



The characters of a bone thus expanded are easily discerned. Its substance may be irregularly cancellous or porous; but the most striking change is a more or less extensive and wide separation of the concentric laminæ of the walls of the bone, so that, as in the section of this femur (fig. 40), the longitudinal section of the enlarged wall

* In the College Museum, Nos. 593 to 600, and 3085 to 3094; and in the Museum of St. Bartholomew's, Series i. Nos. 56, 94, 138, 196, 197, 198, &c.

† From a specimen in the Museum at St. Bartholomew's, Series i. No. 94.

appears composed of two or more layers of compact tissue, with a widely cancellous tissue between them : and these layers may sometimes be traced into continuity with those forming the healthy portion of the wall. Usually, the separated layers are carried outwards, and the bone appears outwardly enlarged ; but sometimes the inner layers of the wall are pressed inwards, and encroach upon the medullary tissue. In the first periods of the disease, the cancellous tissue between the separated layers of the wall has wide spaces, which are usually filled with a blood-coloured medulla : but this tissue, like the often coincident external formations of new bone, appears to have a tendency to become solid and hard ; and its fibrils and laminæ may thicken till they coalesce into a compact ivory-like substance, harder than the healthy bone.

Again, for examples of softening in inflammation, I may adduce the softening of ligaments, such as permits that great yielding of them which we almost always see in cases of severely inflamed joints. This is not from mere defective nutrition ; for it does not happen in the same form, or time, or measure, in cases of paralysis or paraplegia engendering extreme emaciation. Neither is it from the soaking of the ligaments with the fluid products of the inflammation ; for it does not happen in the abundant effusions of the slighter inflammations of the joints ; and when ligaments are long macerated in water they yet retain nearly all their inextensibility. It appears to be a peculiar softening, or diminished cohesion, of the proper tissue of the ligaments ; the result of a degeneration, combined with infiltration of inflammatory products.

We may see such changes in the ligaments of all joints ; in the hip, in the cases of spontaneous dislocation occasionally seen, independent of suppuration or ulceration of the parts

belonging to the joint ; in the wrist, when the ulna after disease becomes so prominent ; in the vertebræ, especially in the ligaments of the atlas and axis. But we see the effects of this softening best in diseased knee-joints and elbow-joints ; and in all these cases we may often observe an interesting later change when the inflammation passes by. The ligaments, softened during the inflammation, yield to the weight of the limb, or more rarely, to a muscular force, and the joint is distorted. Then, if the inflammation subsides, and the normal method of nutrition in the joint is restored, the elongated ligaments recover their toughness, or are even indurated by the organization and contraction of the inflammatory products deposited in them. But they do not recover their due position ; and thus the joint is stiffened in the distortion to which its ligaments had yielded in the former period of inflammation. In the crowds of stiff, distorted, and yet not immoveably fixed, joints, that one sees as the consequences of inflammation, these changes must generally have happened to the ligaments : first softening and yielding ; then recovery, with induration, and perhaps some contraction, due to their atrophy and the organization of the inflammatory deposit. The cases are aggravated by similar changes in the adjacent parts ; for the stiffness of such joints is not due to the ligaments alone ; all the subcutaneous tissues are apt to be adherent and indurated.

The *absorption* of the affected tissues is another example of the destructive changes ensuing in the inflammatory process. Like the degenerations, which, probably, always precede it, it is, in many inflammatory conditions, a peculiarly rapid event ; and it may affect, at once, the proper elements of a part, its blood-vessels, and the inflammatory

products that may have been previously deposited among them.

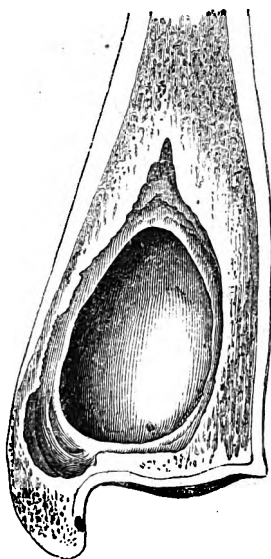
I shall refer here only to that which has been called *interstitial absorption*; to the removal of parts from within the very substance of the tissues, as distinguished from the removal by the ejection of particles from the surface, of which I shall afterwards speak as occurring in *ulceration*.

Interstitial absorption of inflamed parts is seen very well in inflamed bones. The head of a bone may be scarcely enlarged, while its interior is hollowed out by an abscess; what remains of the bone may be indurated, as by slight and tardy inflammation, but so much of the bone as was where now the abscess is, must have been inflamed and absorbed. The changes are well shown in the instance of abscess in the lower end of the tibia which is here drawn (fig. 41).*

Here, too, the evidence of absorption is completed by the similar excavations formed in bones within which cysts and tumours grow; for in these cases no other removal than by absorption seems possible.

To similar absorption of inflamed tissue we may refer

FIG. 41.



* Museum of St. Bartholomew's, Ser. i. No. 82.

the wasting that we notice in the heads of bones that have been the seat of chronic rheumatism. The best examples of this are in the head and neck of the femur; and the retention of the compact layer of bone, covering-in the wasted cancellous tissue of the shortened neck and flattened head, is characteristic of interstitial absorption, as distinguished from ulceration, by which the cancellous tissue is commonly exposed. In these cases of chronic inflammation of the bones, we may notice, also, an appearance of degeneration that precedes a peculiar mode of absorption or of ulceration. While the articular cartilages are passing through the stages of fibrous degeneration, and are being gradually removed, the subjacent bone is assuming the peculiar hardness which has been termed "eburnation," or "porcellaneous" change. Now this change is effected by the formation of very imperfect bone; of bone that has no well-formed corpuscles; and it resembles the result of mere calcareous degeneration rather than a genuine ossifying induration. And its character as a degeneration is further declared in this; that it is prone to destructive perforating ulceration, which often gives a peculiar worm-eaten appearance to the bones thus diseased.*

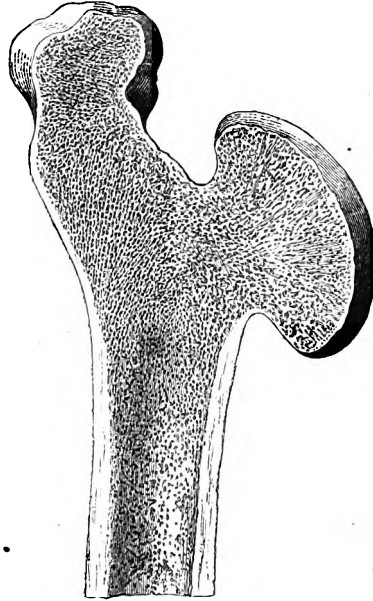
With these changes in rheumatic bones we may also cite, as instances of absorption during slow inflammation, the changes which Mr. Gulliver† first described as apt to ensue

* A change, which appears to correspond with the eburnation of bone, is described by Mr. Tomes, as occurring in a part of a tooth which lies beneath a carious cavity. In both cases the induration might suggest that it is calculated to retard the progress of the disease, but we have no evidence that it does this in an effective manner; and in the case of the bones there is every appearance that the destruction is most rapid where there is most induration.

† Edinburgh Med. and Surg. Journal, vol. xlvi. His illustration

after injuries about the trochanter of the femur (fig. 42). In such cases, without any appearance of ulcerative destruction, the head and neck of the femur may waste by absorption, the neck becoming shortened and the head assuming a peculiar conical form. We might regard these effects as simple atrophy, if it were not that they are like the effects of the more manifest inflammation in the rheumatic cases, and that the existence of inflammation during life is often declared by the abiding pain and other symptoms following the injury.

FIG. 42.



Again, other examples of the absorption of inflamed parts, or of parts that have been inflamed, are presented in the wasting of glands after inflammation; as in cirrhosis of the liver, in some forms of granular degenerations of the kidney, in the indurated and contracted lung after pneumonia.

No doubt, in these cases, the reduction of the organ

of a well-marked case is here copied.—The change is illustrated in No. 3312 in the College Museum.

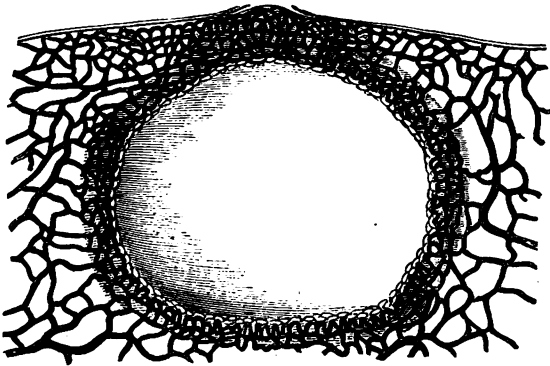
depends, in a measure, on the contraction of the diffused inflammatory product, as it organizes; but in many cases the quantity of new tissue is extremely small (it is so in the shrivelled granular kidney); and, in all the cases, we may well doubt whether the contraction of organizing lymph would produce such extensive and uniform absorption of the proper substance of an organ, if there were not a previous condition favouring the absorption. The most probable explanation of these cases seems to be, that as, in the early periods of the inflammation, the softening and the degeneration of the inflamed tissues coincide with the production of the lymph; so, as the inflammation subsides, and subsequently, the absorption of the degenerated tissues may often coincide with the full organization and contraction of the lymph. And it is altogether most probable that these events are independent though concurrent; and that each occurs as of itself, not as the cause or consequence of the others.

To all these cases must be added the fact of the absorption of the blood-vessels, and other accessory apparatus, of the inflamed tissues. The absorption of the absorbents themselves must coincide with that of the tissues. What a problem is here! These, that had once been the apparatus maintaining life, that had been adjusted to its energy and fashion, now, as it fails, remove themselves in adaptation to its failure. How can this be? We can only guess that its method is just the reverse of the method of formation; that, as in growth the blood-vessels and lymphatics follow in the course of evolution of the growing parts, opening and extending into each new part as it forms, so, in decrease, they follow, and closing-in harmoniously with the general involution, mingle their degenerate materials with those of the tissue, and are absorbed by the nearest remaining streams of blood.

Once more ; not only the original elements of the tissues may be absorbed, but, even more rapidly, the new-formed products of inflammation. We have the best example of this, as well as, indeed, of many of the facts which I have been mentioning, in the spontaneous opening of a common abscess ; which, though it be so common a thing, I will venture to describe here.

Let us suppose the case of an abscess formed in the subcutaneous tissue ; of such an one as I described some pages back, and may illustrate by this sketch of an imaginary section through its cavity and the superjacent skin (fig. 43). It has had its origin in lymph infiltrated through

FIG. 43.



a certain area of the tissues, and forming therein a hard circumscribed inflamed mass. Of this lymph all the central portion is suppurated, and forms the purulent contents of the abscess ; while the peripheral part acquires more abundant blood-vessels, assumes the character of a granulation-layer on its surface, and forms the proper wall of the abscess.

The pus of such an abscess as this will contain, pro-

bably, besides its proper constituents, some of the disintegrated tissue of the part in which it has its seat. We cannot, indeed, be quite sure of this; for it may be, that while the lymph is being formed, or being converted into pus, the proper tissue of the infiltrated part is undergoing absorption; and although, in the pus of abscesses thus formed, we often find abundant molecular and granular matter, yet this may be the débris, not of the tissue, but of the cells or fibrine of the inflammatory product. We cannot, I think, be sure on this matter; but we may be sure that one of these two events occurs; that the circumscribed portion of tissue, in which such an abscess has its seat, degenerates; and is then either absorbed, or else disintegrated, so as to mingle more or less of its substance with the pus.

The abscess thus formed has a natural tendency to open, unless all the inflammation in which it had its origin subsides. Inflammation appears to be not only conducive, but essential, to the spontaneous opening of abscesses; for, where it is absent, the matter of chronic abscesses will remain, like the contents of any cyst, quiet for weeks, or months, or years; and when in chronic abscesses, or in cysts, inflammation ensues through the whole thickness of their coverings, it is usually certain that their opening is near at hand. This difference between acute and chronic abscesses makes it very doubtful whether the inflammation of the coverings of an abscess can be ascribed to any local influence of the pus. But to whatever it may be ascribed, we may refer to this inflammation, and to the degenerative changes that accompany it, the comparatively quick absorption of the integuments, and of the infiltrated lymph, over the collection of pus: and thus the fact, however we may account for it, that the integuments are more prone to in-

flammation, and more actively engaged in it, than the other tissues about an abscess are, may be used to explain the progress of matter towards the surface. Possibly (though this, I think, is much less probable) the tissues and the lymph between an abscess and the surface may, after the degeneration which accompanies the inflammation, be disintegrated, and may mingle their molecules with the purulent contents of the abscess. But, in favour of the belief that they are absorbed, we have the evidence of analogy; for just the same thinning and removal of integuments takes place when they inflame over a chronic abscess with a thick impenetrable cyst, or over an encysted or even a solid tumour. In these cases, absorption alone is possible; and the cases are so similar to the ordinary progress of abscesses, that I think we may assign all the changes of the integuments over these to the same interstitial absorption.

During, or preparatory to their absorption, the integuments over an abscess become softer and more yielding. The change is, most probably, due to such softening as I have described in degenerating inflamed parts. It takes place especially in the portion of the integuments over the middle, or over the most dependent part, of the abscess; and this most softened portion, yielding most to the pressure of the pus, becomes prominent beyond the parts around it, and *points*. Mr. Hunter refers to this as "the relaxing or elongating process." He says: "Besides these two modes of removing whole parts, acting singly or together [that is, besides the interstitial and the progressive absorption], there is an operation totally distinct from either, and this is a relaxing and elongating process carried on between the abscess and the skin, and at those parts only where the matter begins to point. It is possible that this relaxing, elongating, or weakening process, may arise in

some degree from the absorption of the interior parts ; but there is certainly something more, for the skin that covers an abscess is always looser than a part that gives way from mere mechanical distension, excepting the increase of the abscess is very rapid.

“That parts relax or elongate without mechanical force, but from particular stimuli, is evident in the female parts of generation, before the birth of the foetus ; they become relaxed prior to any pressure. The old women in the country can tell when a hen is going to lay, from the parts becoming loose about the anus.”*

While these changes of degeneration, leading to softening and absorption, are ensuing in the cutis and the lymph over such an abscess as I have described, we commonly notice that the cuticle separates, leaving the very point, or most prominent part, of the abscess bare (fig. 43). The cuticle is sometimes raised as in a blister ; but much more often it cracks and separates, and then, with its broken edges raised, peels-off like dead cuticle : and we may believe that it is dead, partaking in the failure of nutrition in which all the parts over the abscess are involved, and being removed as a dead, not as a merely degenerated, part.

At length, after extreme thinning of the integuments, they perish in the centre of the most prominent part.— Sometimes the perished part becomes dry and parchment-like, with a kind of dry gangrene ; but much more commonly a very small ordinary slough is formed, and the detachment of this gives issue to the purulent matter. The

* On the Blood, &c. Works, vol. iii. p. 477. The last fact is, probably, not appropriately cited. The change in the state of parts before the birth is most likely due to relaxation of the abundant muscular fibres that they all contain.

discharge is usually followed by a more or less complete cessation of the inflammation in the integuments, and then the wall of the abscess, having the character of a cavity lined with healthy granulation, heals.

The softening and absorption of inflamed tissues of which I have been speaking, are the chief consequences, or attendants, of minuter molecular changes, to which I must now refer. These changes are derived, as I have already said, from one or both of two sources; namely, the natural degenerations of the inflamed tissues, and their penetration by the inflammatory product.

The rapid softening of an inflamed tissue is, probably, in most cases, dependent on both these conditions; and yet in some cases, and in some measure in all, it may be ascribed to a simple degeneration, such as might be classed with those named liquefactive. Thus, in the case of the integuments over an abscess, we find it associated with infiltration of degenerating lymph-products, and probably in some measure due to their presence: but in the brain and spinal cord, the softenings of inflammation are, in structure, and probably also in nature, very like those of mere atrophy.

Less rapid softening is often connected with a well-marked fatty degeneration of the inflamed tissues. This is especially the case in the muscles, bones, cartilages, cornea, and certain glands, as the liver and kidney.

I found such a degeneration well marked in the fibres of the heart of a man, who thrust a needle through his left ventricle four days before his death. There were evident signs of pericarditis, and of inflammation of the portion of the heart close by the wound; and both in this portion, and, in a less degree, in all other parts of the heart, I found such a fatty degeneration of the muscular fibres as I could not have distinguished from that which occurs in the corre-

sponding atrophous degeneration.* The same changes may be oftener observed at later periods after inflammation of the substance of the heart ; and in some of these cases the interstitial deposits of lymph are organized into fibrous tissue, while the muscular fibres themselves are degenerate. The extended observations of Virchow, on the inflammations of muscles,† show that such fatty degeneration of the fibres usually occurs in nearly all but the most acute cases ; in these, softening and disintegration of the muscular fibrils rapidly ensue, and fatty particles appear subsequently, if at all, in the inflammatory exudation and disintegrated tissue that are mingled within the sarcolemma. He shows, also, very clearly, how the changes in the muscular fibres may be associated with the effects of lymph deposited interstitially among them, as well as within them, and passing through its ordinary progress of development or degeneration ; and that they may be followed by the complete wasting, or absorption, of the degenerate tissue, in the place of which the new fibrous tissue formed by the developed lymph may remain like a scar or a tendinous spot.

In inflamed bone, also, Virchow has traced fatty degeneration as a part of the process of softening which precedes its expansion or absorption. The change is observed not constantly, yet very often, as a fatty degeneration of the bone-corpuscles, in the interior of which small fatty mole-

* I spoke with some hesitation about this case when the lecture was given ; for I could scarcely believe in the occurrence of such an acute degeneration. The admirable observations of Virchow (Archiv, B. iv. H. i.) leave no doubt that such a change is a general attendant of inflammation of muscles. Few things could be more assuring than to find the opinions I expressed concerning this and other parts of the inflammatory process completely confirmed by him.

† In his Essay on Parenchymatous Inflammation, cited above, p. 266.

cules appear. After, or sometimes without, such previous changes in the corpuscles, he has also traced their enlargement and the gradual softening, disintegration, and final liquefaction and separation of the proper bone-substance, immediately surrounding and including each corpuscle. The changes he has thus traced accord completely with those described by Goodsir and Redfern in the cartilage; and, as he well observes, they have peculiar interest in relation to the occurrence of degeneration, as a part of the inflammatory process, inasmuch as they are the results of the same process as that by which, normally, the medullary spaces and areolæ of growing bone are formed, by which, as the bone grows, the compact cortical tissue is gradually changed into areolar or spongy tissue, and by which the peculiar "mollities ossium," or "osteomalacia," is produced.

Changes like these in inflamed bone have been found in ulcerating and articular cartilage; and they are here the more important, as showing a process essentially similar to the degeneration of inflammation, although occurring in a tissue that has no blood-vessels, and into which we have no evidence of the penetration of lymph. They have been chiefly observed by Dr. Redfern;* but have been confirmed by many. They consist, essentially, in the enlargement of the cartilage-cells, with increase of the nuclei, or of peculiar corpuscles contained in them, or with fatty degeneration of their contents, and fading, or similar degeneration of their nuclei. The hyaline intercellular substance at the same time splits-up, and softens into a gelatinous and finely molecular and dotted substance, or else is gradually trans-

* Anormal Nutrition in Articular Cartilages: Edinburgh, 1850. And "On the Healing of Wounds in Articular Cartilages," in the Monthly Journal of Medical Science, Sept. 1851.

formed, in the less acute cases, into a more or less fibrous tissue. The enlarged cartilage-cells on the surface are released, and may discharge their contents on the surface of the ulcer; and the intercellular substance is gradually disintegrated and similarly discharged, or, whatever part of it remains, is transformed into fibrous tissue, and becomes the scar by which the ulceration is, in a measure, healed.

Lastly, in the cornea, a series of observations on the effects of inflammation, purposely excited in it by various stimuli,* have shown that the changes in it are not due to any free exudation of lymph in it, but to alteration in its proper constituent textures. They consist, chiefly, in swelling and enlargement of its corpuscles, the appearance of minute fatty molecules in them, and the increase and enlargement of their nuclei. The intercellular substance becomes, at the same time, turbid, more opaque, denser, more fibrous, and, sometimes, finely granulated; and in some cases fatty molecules appear in it. The changes thus produced in the cornea are not essentially different from those that follow its idiopathic inflammations; and, as Virchow concludes, they are extremely like those of the arcus senilis.

Now, from all these cases, with which others of similar import might be combined, we may conclude that the degeneration of the proper tissues of inflamed parts, which we recognize in the mass as a softening of their substance, or an aptness to be absorbed, is, very often, essentially like the fatty degeneration which we have studied as a form of atrophy of the same parts; that the changes of structure

* They are published briefly in Virchow's essay already cited; and in detail in a dissertation—"Der normale Bau der Cornea und die pathologischen Abweichungen in demselben," Würzburg, 1851—by Fr. Strube, by whom the observations were made under the superintendence of Virchow.

are, in both, essentially the same; differing in rate of progress, but not in method or result. And the cases of the bones, cartilages, and cornea, are the more to be considered, because the changes described in them cannot be referred, in any considerable measure, if at all, to a process of exudation into the elements of their tissues.

The fatty degeneration and that of softening, as by progressive liquefaction, are, doubtless, the most general forms in which the defective nutrition in an inflamed part is manifested. But something allied to the calcareous degeneration occurs in the ossifications of the laryngeal cartilages when they are involved in inflammation, and of such other cartilages as are prone to an imperfect ossification in old age. These are frequent events; and as Virchow observes, the ossification occurs constantly and often exclusively in the very part of the cartilages which corresponds with the seat of the inflammation. To the same class of cases we may refer the ossifications of parts of the articular cartilages in chronic rheumatic arthritis (p. 366), and the formation of the imperfect dentine or osteo-dentine which ensues in inflammatory affections of the tooth-pulp, or in the pulp of the elephant's tusk round bullets lodged in it. In all these cases, it may be observed, the inflammatory process is attended with such changes as occur almost normally at some later period of life, or in old age; such changes, then occurring, are reckoned among the natural degenerations, the signs of simply defective formative power: the difference, therefore, between the natural degeneration and that of the inflammatory process seems to be one of time more than of kind; the inflammatory is premature and comparatively rapid, and ensues with the characters of disturbed, rather than of merely defective, nutrition.

Such are some of the evidences of degeneration ensuing in the proper tissues of inflamed parts. The cases I have

selected are of the simplest kind ; whose results are least confused by the changes that may ensue in lymph penetrating the degenerating tissue. When this happens, it is perhaps impossible, at present, to separate the two series of changes : those, I mean, which are due to the degeneration of the elements of the tissue, and those which are occurring in the lymph within them. The latter are especially described by Virchow in the muscular fibres, and in the renal cells, in what he calls the parenchymatous form of granular degeneration of the kidney. In the latter he says,* that while, as in the croupous form, fibrinous cylinders of free inflammatory exudation may be found in the straight, and a part of the convoluted tubes, other changes are ensuing in the epithelial-cells ; and by these chiefly, and sometimes alone, the characteristic altered structure of the kidney is induced. They occur especially in those parts of the tubes which run transversely or obliquely. In the first stage of the disease these cells enlarge, and their molecular nitrogenous contents increase, by the penetration of the inflammatory product into them. In the second stage, the increase is such that the cells break-up, and the urine-tubes appear filled with a molecular albuminous substance ; or else the fatty transformation ensues in them, and they are filled with finely granular fatty matter, and appear as granule-cells, or granule-masses. In the third stage the fat-granules dispart, and an emulsive fluid is formed which may be absorbed or discharged with the urine.

Virchow describes similar changes in the hepatic-cells : but it may suffice only to refer to these. What has been already described will be enough, I hope, to justify the expressions used at the beginning of the lecture : namely,

* In his essay, referred to at p. 320. Many of his facts were published by one of his pupils, Dr. Niemann, in his dissertation, *De inflammatione renum parenchymatosa*, Berol. 1848.

that the changes (short of death) which ensue in the proper elements of an inflamed part are two-fold : first, those of a degeneration, such as might ensue in simply defective or suspended nutrition ; and secondly, those which depend on the penetration of the exuded inflammatory product. Either of these may, perhaps, occur alone, but the first can be rarely, if ever, absent. When they are concurrent, their several effects cannot be clearly separated ; and when they both take place rapidly, the degeneration is apt to lose all likeness to such as naturally occur, and to appear as only contributing to the rapid disintegration and liquefaction of both the tissue and the inflammatory product. This appears to be the case in many instances of ulceration ; a process which I have deferred to the very end of the history of the inflammation, because all the other parts of the disease appear to be engaged in it.

I need hardly say that, ever since Hunter's time, confusion has existed in the use of the terms employed for various kinds or methods of absorption and ulceration. Of all that Hunter wrote, nothing, I think, is so intricate, so difficult to understand, as his chapter on ulcerative inflammation ; and much of the obscurity in which he left the subject remains. Some of this depends on the same terms having been used in different senses, and may be avoided if it is agreed to speak of the removal of those particles of inflamed parts, which are not on an open or exposed surface, as the " interstitial absorption " of inflamed parts. Then, the term " ulceration " may be employed to express the removal of the superficial or exposed particles of inflamed parts : or, rather, when the epithelium or epidermis of an inflamed part is alone removed, it may be called " abrasion " or " excoriation ; " and when any of the vascular or proper tissue is removed from the surface, it may be

called "ulceration." If, in such ulceration, the superficial particles may be supposed to be absorbed, the process of removing them may be termed "ulcerative absorption;" but if, as is more probable, their removal is effected entirely by ejecting them from the surface of the inflamed part, then the term "ulceration" may sufficiently express this ejection, and will stand in stronger contrast to the "interstitial absorption" of the particles that are not so ejected, but are taken into the blood.

I have lately referred to the uncertainty whether, as the cavity of an abscess enlarges or opens, the tissues, and the infiltrated lymph, that are removed from the inner surface of its boundary walls, are absorbed, or are disintegrated and mingled with its fluid contents; in other words, whether they are absorbed or ejected. The same uncertainty exists, in some measure, in the case of ulceration, concerning which, indeed, all that was said, (p. 410,) respecting the necessity of inflammation to the opening of abscesses, might be here repeated, inasmuch as inflammation seems essential, not only to the formation, but to the extension or enlargement, of an ulcer. The ulcerative process cannot take place in healthy tissue; previous degeneration of the tissue, and that such as occurs in the inflammatory process, is a condition essential to it.

But, when this condition is provided, is the enlargement of an ulcer effected by absorption of its boundaries, or by the gradual detachment and casting-off of particles from their free surface? Both methods of enlargement may, perhaps, in some cases, ensue; but the probabilities are in favour of the enlargement being, as a general rule, effected by the ejection of particles.

Thus:—1. Parts to be removed from a surface are generally cast-off rather than absorbed, as cuticles of all kinds are, and the materials of secretions; so that, by

analogy, we might assume that the particles of the surface of a spreading ulcer would also be cast-off.

2. The materials of the ulcerating tissue may be sometimes found in the discharge from the ulcer. In most cases, indeed, this is impossible; but perhaps it is so only because, when the tissues, and the lymph deposited in them, are degenerate, and broken-up, or decomposed and dissolved, we have no tests by which to recognise them. In the ulceration of cartilage, however, in which inflammatory exudation has no share, the process of ejection of the disintegrated tissue is clearly traced; and we might deem this almost a proof of the same process being observed in other tissues, if it were not that in the cartilage a necessary condition of absorption, the presence of a circulation, is wanting. The same process of ejection, however, is traceable in ulcerating bone, where absorption might occur. It is shown by the observations which I have quoted from Virchow; and Mr. Bransby Cooper has observed that, while in pus from soft parts only traces of phosphate of lime are found, the pus from around diseased bone contains in solution nearly $2\frac{1}{2}$ per cent.* A similar, but less complete, observation had been made by Mr. Thomas Taylor,† and by v. Bibra;‡ and we may believe that at least some of the phosphate of lime, in these cases, was derived from the diseased bone.§

* Medical Gazette, May, 1845.

† Stanley: Treatise on Diseases of the Bones, p. 89.

‡ Chemische Untersuchungen verschiedener Eiterarten, p. 85.

§ The belief may seem the more reasonable, because of the similar fact of the quick absorption of bone-earths in inflamed but not ulcerating bones. Still, it must be admitted, more evidence is needed that the quantity of bone-earths discharged with the pus is proportionate or equal to the quantity lost by the ulcerating bone. For if what has been said (p. 356) of the conformity of the properties of inflammatory and reparative products with those of the tissues from

3. It strengthens this belief to observe, that, in many cases, small fragments of bone and other tissues are detached, and cast-out with the fluid from the ulcerating part. These, indeed, when they are not fragments of tissue detached by ulceration extending around them, are good examples of the transition that may be traced from ulceration to sloughing or gangrene of parts, between which, if ulceration be always accomplished by ejection, the only essential difference will be one of degree; the ulceration being a death and casting-off of invisible particles of a tissue, while gangrene implies the death and casting-off of visible portions.

4. And it may be proved of many that we call ulcers, that they begin as sloughs which are cast-off, and leave the ulcerated surface beneath. We may often see this, on a large scale, in the instances of what are called sloughing ulcers; but Dr. Baly has proved it for a much wider range of cases, in his observations on dysentery, in which he has traced how even the smallest and the most superficial ulcers of the intestine are preceded by the death and detachment of portions of the mucous membrane, with its covering of basement-membrane and epithelium.*

From these considerations, we may hold it as probable that ulceration is, usually, the result of the detachment of dead portions or molecules of an inflamed tissue, and that the substance removed in the process is not absorbed but

which they are produced, be true, then will also pus from diseased bone possess more bone-earths than pus from any other tissue, even though the bone be not ulcerating. Granulations upon bone doubtless contain more bone-earths than those on soft parts, and they may ossify: now the relation of pus to granulations is commonly that of degenerating cells to the like cells developing; therefore we might expect that pus from bone, like granulations from bone, will contain a large proportion of bone-earths, independent of what may be derived from the ulceration of the bone.

* Gulstonian Lectures: Medical Gazette, 1847.

ejected. There are, indeed, some cases which may make us unwilling to admit, at present, that all ulceration is by ejection ; such as those of bone ulcerating under cartilage, or in the rapid extension of inflammation within it, or such as the spreading ulceration of the vertebræ, or of the heads of bones, that is not attended with external discharge of fluid. These may, for the present, interfere with the universality of the rule, but not with its generality.

But, if we may believe that the removal of a tissue by ulceration is generally effected by ejection of its substance, the question may be asked, in what form is it ejected ? Dr. Baly's observations enable us to say that, in the first instance, a visible slough is detached, a portion of the tissue dying and being disconnected from the adjacent living tissue. But, after this is done, when an ulcer enlarges, or extends and spreads, is the material of the tissue still removed in visible sloughs or fragments ? Certainly it is so sometimes ; for we may find little fragments of bone in the discharge from ulcerating bone, especially in strumous ulceration. But in other cases we have no evidence of this kind ; we cannot detect even microscopic fragments of tissues in the discharges, and we must suppose that they are removed, in a state of solution or of molecular division, in the discharge from the diseased part.

To speak of the solution of tissues in the discharges of ulcers may seem like the revival of an old error long since disproved. But though the expression may be revived, it is with a new meaning. The proof has, truly, been long completed, that healthy tissues, even though they be dead, cannot be dissolved in pus, or any such discharge ; but the tissues that bound or form the walls of a spreading ulcer are not healthy ; they are inflamed, and, as I have been just saying, their elements, and the products of inflammation in and among them, are degenerate, so that they may

be now minutely divided, or even soluble in fluids that could not dissolve them while they were sound. Insolubility is as great an obstacle to absorption as to ejection in discharges; no tissue can be absorbed without being first so far changed as to be soluble in fluids with which it was before in contact and unharmed. Therefore, whether we hold the ordinary spreading of an ulcer to be by absorption of its boundaries, or ascribe it to their ejection, we must, in either case, admit that they are first made soluble. And if this be admitted, then it is most consistent with analogy, and most probable, that the extension of an ulcer, independently of sloughing, is accomplished by the gradual degeneration of the tissues that form its walls, and by their being either disintegrated and cast-off in minute molecular matter, or else dissolved and ejected in solution in the discharges from the ulcer.

The solution here spoken of is such as may be effected by the fluid discharged from any spreading ulcers; but we may doubt whether all discharges from ulcers possess a *corroding* property, such as Rokitansky seems to ascribe to them, and such as he considers to be the chief cause of the extension of all ulcers. We may doubt, I say, whether all ulceration can be described as a corrosion or erosion of the tissues by ichor; but, on the other side, we cannot well doubt that the properties of the discharge from an ulcer, or a sloughing sore, may have a great influence in accelerating the degeneration and decomposition, and thereby the solution, of the tissues that form its walls or boundaries. Many ichorous discharges from ulcers inflame and excoriate the parts over which they flow, and thus inflaming them, they promote their degeneration, and lead them more readily to enter into the ulcerative process. Many such discharges, also, are in an active state of decomposition; and their contact with the inflamed tissues cannot but have some

tendency to excite decomposition in them; a tendency which the tissues will be the less able to resist, in the same proportion as they are already feebly maintaining themselves, or as they have been moved by inflammation from their normal conditions, and their normal tenacity of composition.

On the whole, then, we may conclude, respecting the process of ulceration, that its beginning is usually the detachment of a slough, or portion of dead tissue, by the removal of the layer of living tissue that bounded it; that the spreading of an ulcer, independent of such visible sloughing, is effected by the inflamed tissues that bound it becoming degenerate, and being detached in minute particles, or molecular matter, or being decomposed and dissolved in the fluid discharge or ichor; and that this spreading may be accelerated by the influence of the discharge itself, which may inflame the healthy tissues that it rests on, and may exercise a decomposing "catalytic" action on those that are inflamed already.

I need hardly say that we have no knowledge by which to explain the peculiar and characteristic forms of certain ulcers. We seem wholly without a guide to such knowledge; but the existence of such specific forms is conclusive against the supposition that the extension of an ulcer is entirely due to corrosion by an exuded fluid. Such a fluid would act uniformly, unless the various effects of disease on the tissues bounding the ulcer should make them variously amenable to its influence.

We have as little knowledge of the nature and real differences of the various fluids discharged from ulcerating surfaces,—the various kinds of ichor* that they yield.

* I think it would be useful to employ the term ichor exclusively

They consist, generally, of fluid exuded from the surface as an inflammatory product, and holding in suspension or solution the disintegrated materials of the ulcerating tissue, and of the lymph infiltrated in them. The inflammatory product exuded on a spreading ulcer has, indeed, the constituents of lymph or pus; but they appear immature or degenerate, consisting of abundant molecular matter, with flakes of soft, dotted fibrine, and ill-formed lymph- or pus-cells, floating in an excess of liquid. Such a substance is, probably, always incapable of organization, both because of its own defect, and because of the inflamed state of the parts it is in contact with. The differences that may, from the first, exist in the several examples of ichor are moreover quickly increased by the various chemical transformations that they undergo. Rokitsansky alone has endeavoured to enumerate the varieties of property that may hence issue, and the influences they may exercise in the maintenance of the disease.†

As from other inflammatory processes, so from ulceration, we may trace the transitions to the healing process. In the case of ulcerated cartilage, Dr. Redfern's researches show that the healing is accomplished, mainly, by the complete transformation of the remaining cartilage-substance into fibrous tissue. Here is no proper process of exudation, for here are no interstitial blood-vessels; the materials of the tissue itself, by transformation, form the scar.

for those discharges mixed with exudation that take place from ulcerating, *i. e.* from progressively ulcerating or sloughing surfaces. For, although it may be often impossible to distinguish, by any manifest properties, such ichor from some of the thinner kinds of pus, yet, if the account of suppuration and of ulceration be true, a constant difference between pus and ichor will be, that the latter contains disintegrated materials of the ulcerating tissue, the former does not.

* Pathologische Anatomie, B. i. p. 213.

But in the vascular tissues, the reparative material is the lymph infiltrated in them at and near the boundaries of the ulcer. As the inflammation subsides, (for here, as in other cases, the inflammation that produced the lymph must cease for its development) the lymph passes through changes like those described in the abscess-wall, and the tissues in which it was infiltrated may, perhaps, recover from their degeneration. Part of the lymph, increased by fresh exudation, assumes the characters of granulations, which, as we watch the progress of an improving ulcer, assume daily more of the characters of those on healing open wounds. We cannot, indeed, mark the very act, or tell the hour, at which the inflammatory process was changed for the reparative; at which the degeneration ceased, and development began; there are no hard boundary lines here, or in any passage from disease to health; but the change is gradually accomplished, and is manifest both in the organizing material of the granulations, and in the pus which takes the place of the ichor, and exactly resembles that of the healing granulating wound. The ulcer is no longer ulcerating; but healing; and the histories of the healing ulcer, and of the healing wound, might be told in the same words.

LECTURE XVIII.

NATURE AND CAUSES OF INFLAMMATION.

THE several parts of the inflammatory process have been now considered. They are—increased fulness of the blood-vessels, with retarded movement of the blood; swelling; pain, or other morbid exalted sensation; increased heat; exudation of lymph from the blood-vessels; defective nutrition of the proper elements of the affected part. The first five are often spoken of as the signs of inflammation, the last two as its effects; but these terms have reference only to the former being more transitory phenomena than the latter: they are all, when they concur, constituent parts of the disease; but the latter are less quickly recovered from than the former.

It would not be judicious, I think, to refuse to call that process inflammation, in which any one of the conditions just enumerated is absent or unobserved. Swelling, or pain, or, much oftener, increased heat, may be inappreciable in tissues that we may still rightly call inflamed, while the other evidences of the disease are present. The same may be said of increased or altered exudation from the blood-vessels. No such exudation is observed in the diseased cornea or articular cartilages; but it would be unreasonable, in the case of an inflamed eye, to say that the changes are due to inflammation in every part but the cornea; and to call the process leading to the ulceration or leucoma of the

cornea by a name different from that which we give to the coincident and similarly excited process in the other tissues. So, during the inflammation of a joint, it would be, at the least, inconvenient, to say that all the tissues are inflamed except the softening or ulcerating cartilages. The progressive degeneration of tissue is, probably, never absent when the other parts of the inflammatory process exist; but, in quickly transitory cases, it is often inappreciable. The altered state of the circulation may be unobserved: but it is, probably, always present; for in the case of the parts that have no interstitial blood-vessels, inflammation may still be attended by enlargement of those of adjacent parts, on which their ordinary nutrition depends.

The conclusion, then, may be, that in what may be regarded as well-marked or typical examples of inflammation, all the characters I have enumerated are present as concurrent parts of the disease; but that the same name should not be refused to diseases in which any one of these parts is absent or unobserved, especially when its absence may be explained, as in the case of inflamed cartilages, by some peculiarity of tissue or other condition of the disease. I think it would not be right to call any process inflammation in which there is neither an exudation of lymph (*i. e.* of material capable of such developments or degenerations as I have described), nor a deterioration of the proper tissue of the affected part; even though the other characters of the disease might be present. But, really, whatever rule of nomenclature be adopted, we may expect to meet with many cases in which we shall doubt what name to give to the processes which we watch, or of which we see the results. There is neither here, nor in any other part of pathology, anything like the unity, or circumscription, of species by which the zoologist, whose nomenclature pathologists are prone to imitate, is justified in attaching to each specific name the idea

of several constant and unalterable characters in the beings to which it is assigned.

An examination of the very nature of the process of inflammation may best be made in the form of a comparison of its effects with those of the normal process of nutrition. And this comparison may be drawn with two principal views; namely, to determine—1st, how the effects of inflammation differ, in respect of *quantity*, from those of the normal process; and 2d, how they differ from the same, in respect of *quality* or *method*.

The decision on the first of these points may seem to be given in the term "increased action," which is commonly used as synonymous with inflammation. As used by Mr. Hunter, this term was meant to imply that the small vessels of an inflamed part are more than naturally active, in formation or absorption, or in both these processes. This is, probably, the meaning still generally attached to the term by some; while, as employed by those who believe the vessels are only accessories in the work of nutrition, the expression "increased action" may be used to imply merely increased formation, or increased absorption. In either, or in any, meaning, however, the term seems to involve the idea of an increased exercise of vital forces, *i. e.* of those forces through the operation of which the various acts of organic formation are accomplished. But, if "increased action" is to imply this, the description of the process and effects of inflammation shows that the term cannot be properly used, without some limit or qualification.

If we consider the quantity of organic formation effected during the inflammatory process, in the proper substance of the inflamed part, it is evidently less than in health. All the changes described in the last lecture are examples of

diminished or suspended nutrition in the tissues of the inflamed part: they are all characteristic of atrophy, degeneration, or death. The tissues become soft, or quite disorganized; they are relaxed and weakened; they degenerate, and remain lowered at once in structure, chemical composition, and functional power; or else, after degeneration, they are absorbed, or are disintegrated, or dissolved, and cast out; they die in particles or in the mass. During all the process of inflammation, there is no such thing as an increased formation of the natural structures of the inflamed part; they are not even maintained; their nutrition is always impaired, or quite suspended. It is only after the inflammation has ceased that there is an increased formation in some of the lowly organized tissues, as the bones and cellular tissue.

So far, then, as the proper substance of the inflamed part is concerned, there appears to be decreased action; that is, decreased formation. There may be, indeed, an increased absorption; but this is also, in one sense, characteristic of decreased exercise of vital force; since all absorption implies a previous degeneration of the part absorbed. Nor can we justly call this, in any sense, "increased action," till we can show how absorption is an action of vessels.

Thus far, one of the constituents of the inflammatory process, one of the characters in which it differs, in respect of quantity, from normal nutrition, is a defect in the nutrition of the proper substance of the inflamed part.

But it is characteristic of the complete process of inflammation, that, while the inflamed structure itself suffers deterioration, there is a production of material which may be peculiarly organized. Here, therefore, may be an evidence of increased formation, of increased action.

Doubtless, in relation to the productive part of the inflammatory process, the expression "increased action" may

be in some sense justly used ; for the weight of an inflamed part, or of the material separated from it, may be much increased by the formation of organized matter. But the quantity of organized matter formed in an inflammation must not be unconditionally taken as a measure of increase in the exercise of the vital forces : for it is to be observed, that the material formed presents only the lowest grades of organization, and that it is not capable of development, but rather tends to degeneration, so long as the inflammation lasts.

It may be but a vague estimate that we can make of the amount of force exercised in any act of formation ; yet we may be sure that a comparatively small amount is sufficient for the production of low organisms, such as are the fibrinous and corpuscular lymphs of inflammation. The abundant production of lowly organized structures is one of the features of the life of the lowest creatures, in both the vegetable and animal kingdoms. And, in our own cases, a corresponding abundant production is often noticed in the lowest states of vital force ; witness the final inflammations, so frequent in the last stages of granular degeneration of the kidneys, of phthisis, of cancer, and other exhausting diseases. In all these, even large quantities of the lowly organized cells of inflammatory lymph may be formed, when life is at its last ebb. And with these cases those correspond which show the most rapid increase of tubercle and cancer, and of lowly organized tumours, when the health is most enfeebled, and when the blood and all the natural structures are wasting.

From these considerations we may conclude that the productive part of the inflammatory process is not declaratory of the exercise of a large amount of formative or organizing force ; and this conclusion is confirmed by observing that development, which always requires the highest and most

favoured exercise of the powers of organic life, does not occur while inflammation lasts. The general conclusions, therefore, may be, as well from the productive, as from the destructive, effects of the inflammatory process, that it is accomplished with small expenditure of vital force; and that even when large quantities of lymph are lowly organized, such an expression as "increased action" cannot be rightly used, unless we can be sure that the defect of the formative power, exercised in the proper tissue of the inflamed part, is more than counterbalanced by the excess employed in the production and low organization of lymph.

It may be said that the signs of inflammation are signs of increased action. But these are fallacious, if, again, by increased action be meant any increased exercise of vital force. The redness and the swelling of the inflamed part declare the presence of more blood; but this blood moves slowly; and it is a quick renewal of blood, rather than a large quantity at any time in a part, that is significant of active life. An abundance of blood, with slow movement of it, is not characteristic of activity in a part; it often implies the contrary, as in the erectile tissues, and the cancellous tissue of bones.

The local increase of heat is too inconstant to afford ground for judging of the nature of inflammation.* When manifest, it is not, I think, to be exactly compared with that of an actively growing part, or of one which is the seat of "determination" of blood, or of "active congestion." In these cases, the heat is high chiefly because the blood, brought quickly from the heart, is quickly renewed; but, in an inflamed part, the blood is not so renewed; it moves more slowly. The heat may, indeed, be

* See, especially, v. Barensprüng, in Müller's Archiv, 1852, p. 268.

in some measure ascribed to this condition ; for the quickly moving blood around the inflamed part may communicate its heat to that which is moving more slowly. But the proper heat of inflammation, (I mean that which is measurable by the thermometer), cannot, I think, be wholly thus explained. Some of it is, probably, due to the oxydation of the degenerating tissues ; a process which we might safely assume to be rapidly going-on in the more destructive inflammations, and which is, indeed, nearly proved by some of the evidences of the increased excretion of oxydized substances in inflammations, especially by the increase of phosphates in the urine during inflammation of the brain.* It is far from proved, indeed, that this source of heat is sufficient for the explanation of the increase in an inflamed part ; and it may be at once objected that we have no evidence that the hottest inflamed parts are those in which the most destructive processes are going on. Still, in relation to the question, how far the increased heat is a sign of the quantity of formative force that is being exercised, we may argue that, as the general supply of heat in our bodies is derived from oxydation or combustion of wasted tissues or of surplus food, so, in these local augmentations of heat, the source is rather from some similar destruction of organized substances, than from increased formation of them. If it be so, the increased heat will give no ground for regarding the inflammatory process as the result of a greater exercise of formative force than is employed in ordinary nutrition ; none for speaking of it as increased nutrition, or increased action. Rather, this sign may be added to the evidences, that the inflammatory process pre-

* Dr. Bence Jones: On the Contrast between Delirium Tremens and Inflammation of the Brain, *Med.-Chir. Trans.*, vol. xxx. p. 37 ; and Virchow, in his *Archiv*, B. iv. H. 1.

sents, of diminished formative force, and of a premature and rapid degeneration, in the affected part.

In thus endeavouring to estimate the difference between the normal and the inflammatory modes of nutrition, in regard to the quantity of formative or other vital force exercised in them respectively, I have also stated the chief differences in relation to the quality or method of nutrition.

The most general peculiarity of the inflammatory method is the concurrence of the two distinct, though usually coincident, events of which I have spoken at such length; namely, 1st, the impairment or suspension of the nutrition of the proper substance of the inflamed part; and 2d, the exudation, from the blood, of a material more than sufficient in quantity for the nutrition of the part, but less than sufficient in its capacity of development.

By these concurring, it is plainly distinguished from the normal method of nutrition. The same combination of events establishes the chief differences between the inflammatory and every other mode of nutrition in a part. Thus, from all the forms of mere atrophy or degeneration, the inflammatory process, at least in the typical examples, is distinguished by the production of the lymph, which may be organizing, even while the proper tissue of the inflamed part is in process of atrophy, degeneration, or absorption. So far as the tissues inflamed are concerned, some inflammations might be classed with atrophies or degenerations; but the concurrent production of lymph is distinctive of them.

On the other side, the inflammatory mode of nutrition is distinguished from hypertrophy by the failure of the nutrition of the inflamed part itself. So far as mere production and formation of organisms are concerned, some inflammations might be paralleled with hypertrophies; but

the organization of the lymph commonly falls short of that proper to the part in which it is exuded ; and the substance of the part, instead of being augmented, is only replaced by one of lower organization.

And, lastly, from the production of new growths, such as tumours, the inflammatory process is distinguished by this,—that its organized products, though like natural tissues of the body, are usually infiltrated, fused, and interwoven into the textures of the inflamed parts ; and that, when once their development is achieved, they have no tendency to increase in a greater ratio than the rest of the body.

I am well aware that these can be accepted as only the generally distinguishing characters of the complete inflammatory process. Cases might be easily adduced in which the border-lines are obscured ; inflammations confounded on one side with atrophies, on another with hypertrophies, on a third with tumours, and, on others, with yet other local phenomena of disease. But the same difficulties are in every department of our science ; yet we must acknowledge the value of general distinctions among diseases even more alike than these are.

The case that I have chosen for illustrating the general nature of the inflammatory process is one representing the disease in its simplest form and earliest stage, manifesting only the formation of lymph, and such a change as the softening or absorption of the inflamed part. This is but the beginning of the history : but, if the inflammation continues, or increases in severity, all that follows is consistent with this beginning ; all displays the same double series of events, the same defective nutrition of the part, and the same production of low organisms. But these additions are observed : the part is more and more deteriorated, and perishes in the mass, or in minute fragments ; the newly-organized products, not finding the necessary conditions of

nutrition, partake in the degenerative process, and, instead of being developed, are degenerated into pus, or some yet lower forms, or perish with the tissues in which they are imbedded.

Respecting, now, the causes of inflammation, I shall not say more of its exciting causes than that, from the external ones, which alone we can at all appreciate, we may derive a confirmation of the opinion I have expressed concerning the nature of the process. They are such as would be apt to produce depression of the vital forces in a part ; all being, I think, such as, when applied with more severity, or for a longer time, lead, not to inflammation, but to the death of the part. If a certain excess of heat will inflame, a certain yet greater heat will kill : if some violence will inflame, a greater violence will kill : if a diluted chemical agent will only irritate, the same concentrated will destroy the part. The same may be said, I think, of cold, and all the other external exciting causes of inflammation. I am aware that other explanations of their action are given ; but none seems to me so simple, or so consistent with the nature of the process that follows them, as this ; which assumes that they all tend (as it may be said) to depress the vital forces exercised in the affected part. They may be stimulants or excitants of the sensitive nerves of the part, but they lead to the opposite of activity in its nutritive processes. In the reaction which follows the application of some of them, they may seem to have been the excitants of nutritive action ; but, if the inflammatory state ensue, the formative process, we have seen, is really diminished.

The proximate causes, or immediately preceding conditions, of inflammation appear to be various perversions of the necessary conditions of healthy nutrition in a part ; that is, morbid changes in either the supply of blood, the composition of the blood, the influence of the nervous

force, or the condition of the proper substance of the inflamed part. Any one or more of these four conditions of nutrition being changed in quality may initiate an inflammation. A change in quantity more usually produces either an excess or deficiency of nutrition in the part, or some process different from inflammation. Thus, a diminution or withdrawal of the blood without alteration of its quality is usually followed by atrophy, degeneration, or death: a mere increase of blood in a part may produce hypertrophy, or something more nearly resembling inflammation, yet falling short of it. Similar effects may ensue from a mere increase or decrease, or abstraction, of nervous force. Change in the quality, whether with or without one in the quantity, of the conditions of nutrition, appears essential to the production of the phenomena of inflammation.

I will endeavour now to show that inflammation may follow such perversion or qualitative change in each of the conditions of nutrition, even though all the rest of them remain for a time in their normal state: selecting, for this purpose, such cases of inflammation as we may trace proceeding, in the first instance, from the uncomplicated error of a single condition of nutrition.

I. Inflammation may perhaps be produced—it certainly may be commenced, and in some measure imitated—by changes in the blood-vessels; changes attended with alteration of their size, or their permeability, or the other qualities by which they affect the supply of blood to a part. This may be concluded from the similarity to some of the phenomena of inflammation which may be observed in certain cases of mechanical obstruction to the venous circulation. In a case of ascites from diseased heart or liver, the peritoneum often contains coagula of fibrine floating free in the serum, though no organ may present appearances

of having been inflamed. In such a case, moreover, I have found the fibrine developing itself in the form of nucleated blastema, even while floating free. In another case of mechanical dropsy, I have found the fluid of anasarca in the scrotum containing both fibrine and abundant lymph-corpuscles, like those in the fluid of an inflammatory exudation. In like manner, an apparently uncomplicated obstruction at the left side of the heart may produce many of the phenomena of bronchitis. Such as these are the cases through which mechanical congestions of blood connect themselves with inflammation. And if to these we add the constancy of increased vascularity among the phenomena of inflammation, they may be sufficient to make us believe, that disturbances in the circulation of a part may produce some of the principal phenomena of inflammation, even though all the other conditions of nutrition are, in the first instance, unchanged. But I know no other good evidence for the belief; and I think we should not lay much stress on these cases, since they display an imitation of only some parts of the process of inflammation; namely, the fulness of the vessels, the retarded blood, and the exudation of organizable matter. The nutrition of the proper tissues of a part with merely obstructed circulation suffers but a trivial loss or disturbance, in comparison with that which would accompany an inflammation with an equal amount of retardation in the movement of the blood. So far as the exudation in an inflamed part depends on the altered mechanical relations of the blood and vessels, so far may similar alterations alone produce effects imitating those of inflammation; they may also be the beginning of the more complete process; but I believe that the merely mechanical disturbances of the circulation are no more adequate alone to the explanation of the whole process of inflammation, than the

normal movements of the blood are adequate to the explanation of the ordinary process of nutrition.

II. We may speak much less equivocally of the influence of the state of the blood itself in causing inflammations; for there can be little doubt that a very great majority of the so-called spontaneous or constitutional, as distinguished from traumatic, inflammations, have herein their origin. We might anticipate this from the consideration that, in normal nutrition, the principal factors are the tissues and the blood in their mutual relations: but we have better evidence than this, in cases of local inflammations occurring in consequence of general diseases of the blood. Some instances of this are clearly proved, as, *e. g.* in the cases of eruptive fevers, when the presence of morbid materials in the blood is proved by the effects of their transference in inoculation. Scarcely less thoroughly demonstrated are the cases of rheumatism and gout, of lepra, psoriasis, herpes, eczema, erysipelas, and other such affections, whose constitutional nature—in other words, whose primary seat in the blood—all readily acknowledge in practice, if not in theory.

Now, in all these cases, local inflammations are the external signs of the general affection of the blood: and I apprehend, that if any difficulty be felt in receiving these as evidences, that the morbid condition of the blood is the cause of the local inflammation, it will be through doubt whether a general disease of the blood—a disease affecting the blood sent to every part—can produce peculiar phenomena of disease in only certain small parts or organs. But this local effect of a general disease of blood has its illustration in some of the sure principles of physiology; especially in one which I have fully illustrated in a former lecture (p. 27 et seq. and p. 63); namely, that the presence

of certain materials in the blood may determine the formation of appropriate organisms, in which they may be incorporated.

It is in exact parallel with the facts in physiology which I then adduced, that in certain general diseases of the blood, organs are formed, as the products of inflammation, within which the specific morbid material is incorporated. Thus, in small-pox, cow-pox, primary syphilis, and whatever other diseases may be transferred by inoculation, the morbid material from the blood is incorporated in the products of inflammation, which are enclosed within the characteristic vesicle or pustule, or infiltrated lymph, just as, in the cases already cited, the constituents of urine or of medicines are incorporated in the renal cells, which are formed within the substance of the kidney; or just as the constituents of sap are incorporated in fruit.

In the cases of disease produced by a demonstrable virus, we have all the evidence that can be necessary to prove the principle, that a general disease of the blood may be the cause of a local inflammation in one or more circumscribed portions of a tissue. And the analogy is so close, that I think we need not hesitate to receive the same explanation of other inflammations, which I have cited as occurring during morbid conditions of the blood. For although we cannot, by inoculation, prove that a specific morbid material of such a disease as herpes or eczema, gout or rheumatism, has been incorporated in the inflammatory products, yet we find great probability hereof in the many analogies which these diseases present to the inoculable diseases, in their whole history, and, especially, in the decrease or modification of general illness which ensues on the full manifestation of the local inflammation.

If it be asked why a morbid material is determined to one part or tissue rather than another, or why, for example,

the skin is the normal seat of inflammation in small-pox, the joints in rheumatism, and so on, I believe we must say that we are, on this point, in the same ignorance as we are concerning the reason why the materials of sweat are discharged at the skin, those of urine at the kidneys, of bile at the liver, or why the greater part of the albuminous principles are incorporated in the muscles, and of the gelatinous in the bones. We cannot tell why these things are so, but they are familiar facts, and parallel with what I here assume of the incorporation of morbid materials derived from the blood.

Again, it may be said that we need some explanation of the fact that the morbid condition of the blood does not influence the whole extent of any given tissue, but only portions of it. In the secretion of urine, it may be believed that the whole kidney is affected and works alike; but in the assumed separation of the virus of small-pox, only patches of the skin are the seats of pustules; in vaccinia and primary syphilis, only a single point; in secondary and tertiary syphilis, a certain, but sometimes disorderly, succession of various parts; and so on.

It must be admitted that many of the facts here referred to cannot yet be explained. In some cases, however, we can assign, with much probability, the conditions that determine the locality in which a general disease of the blood will manifest itself by inflammation. In some instances, it is evident that the localization is determined by such as we may call a weakened or depressed condition, a state of already impaired nutrition, in some one part. For instance, when a stream of cold air is impelled on some part, say the shoulder, of a person disposed to rheumatism, it determines, as a more general exposure to cold might do in the same person, the rheumatic state of the blood, with all its general symptoms: but it determines, besides, the

part in which that rheumatic state shall manifest itself first or alone. The depressed nutrition of the chilled shoulder makes it more liable than any other part to be the seat of inflammation excited by the diseased blood.

Or, again, when a virus is inserted, as in all cases of poisoned wounds, the local inflammation produced by the disease with which the whole blood is infected will commonly have its seat in the wounded part. The virus must have produced some change in the place in which it was inserted, as well as in the whole mass of the blood. The change is not merely that of a wound ; for a simple wound made in the same person, at the same time, will not similarly inflame ; it is a change due to the direct influence of the virus. And the part thus changed may long remain in a peculiar morbid state, and peculiarly prone to inflammation from diseased blood. Thus, an infant was vaccinated in the middle of June, and the disease had its usual course ; six ordinary vesicles formed in the punctures in the left arm, and common cicatrices remained, and all appeared well. In the middle of July, inflammation of the left axillary glands ensued. When I saw the child on August 21st, the glands were very large, and partially suppurated, and there was extensive inflammation of the skin of the upper arm. On August 30th, the pus having been partially discharged by incision, the glands had subsided, but superficial inflammation of the integuments existed still, and now there was, on the middle of each vaccine cicatrix, a distinct circular low vesicle, not unlike that of the true vaccine eruption, except that it was not umbilicated, and appeared to have an undivided cavity.

Such cases are, probably, only examples of a general rule, that a part whose natural force of nutrition is in any way depressed, is, more than a healthy part, liable to become the seat of chief manifestation of a general blood-

disease. A part that has been the seat of former disease or injury, and that has never recovered its vigour of nutrition, is always so liable; it is a *weak part*. Thus, the old gouty or rheumatic joint is apt to receive the brunt of the new attack. And the same may happen in a more general way. A man was under my care with chronic inflammation of the synovial membrane of his knee, and general swelling about it: he was attacked with measles, and the eruption over the diseased knee was a diffused bright scarlet rash. A patient under Dr. Budd's care had small-pox soon after a fall on the nates: the pustules were thinly scattered everywhere, except in the seat of former injury, and on this they were crowded as thickly as possible. Thus, too, when a part has been injured, and, it may be, is healing, a disease having begun in the blood will manifest itself in this part. Impetigo appears about blows and scratches in unhealthy children; erysipelas about the same in men with unhealthy blood.

Such are some of the cases in which we seem able to explain the apparent choice of locality for inflammation, made by a morbid material which is diffused through all the blood. Many remain unexplained; if it were not so, this portion of pathology would be a singular exception to the general condition of the science. But these difficulties afford no warrant for the rejection of a theory, of which the general probability is affirmed by so many analogies, by the sufficiency of its terms for the expression of the facts, and, it may be added, by nearly every particular in the constitutional treatment of local inflammation. For, I suppose there are few parts of the medicinal treatment of local inflammation, for which any reason can be shown, unless it be assumed that the medicine corrects some morbid condition of the blood.

Let it be added that the state of the blood may, in part,

or chiefly, determine, not only the locality, but also the degree and form of the inflammation. It may, as Dr. Ormerod has well expressed it, "imprint on the morbid product (of inflammation) certain tendencies which take effect after the morbid products have entered upon a condition of comparatively independent existence."* But on this point I need not dwell; for a large portion of Lecture XIV. is devoted to it, and it will be again considered in the Lecture on Specific Diseases.

To test the influence of a disturbance of the nervous force in engendering the inflammatory process, we must not, as is commonly done, take cases of the effects of external injury. Such an injury, or the presence of a foreign body, is supposed to excite inflammation by stimulating the nerves of the part, and by changing, through their influence, the state or action of the blood-vessels. This may be true; but we should remember that when a common injury is inflicted, it acts not only on the nerves of the part, but also on its proper tissues; and it may so affect the state of these tissues, that the changes produced in them may be the excitant of inflammation, independent of the affection of the nerves. All such cases as these are, thus, ambiguous.

For a better test, we must select cases in which the excitant of inflammation acts (at least in the first instance) on the nervous system alone. Such cases are those already referred to (p. 318). When the conjunctiva is inflamed after over-working of the eye, we cannot suppose that the light, by its direct contact, has affected the vessels, or the nutritive act, in the conjunctiva: it can, probably, affect

* In his Lectures on the Pathology and Treatment of Valvular Disease of the Heart, in the Medical Gazette, 1851. These should have been cited before, as containing the fullest demonstration of the principle referred to here, and at p. 336.

either of these only through an influence reflected from the retina. So, when irritation of the urethra excites inflammation in the testicle; when the irritation of teething excites it in any distant part; when, as in a case quoted from Lallemand, by Dr. Williams, inflammation of the brain followed the application of a ligature to part of the brachial plexus; in these and the like cases we cannot but refer to the disturbance of the nervous force as the initiator of the phenomena of inflammation.

Now, for the explanation of such cases as these, there appear to be two chief theories: 1. It may be that the nerves distributed to the minute blood-vessels of a part may be so affected that these vessels may dilate, and their dilatation may produce the other phenomena of inflammation; or, 2. The disturbance of the nervous force may more directly interfere with the process of nutrition, inasmuch as this force exercises always some influence in the nutrition of each part, and is (as one may say) one among the plasturgic forces (p. 39.)

The first of these theories has lately acquired a dominant place in systems of pathology, especially in those of Germany. The principal form of it, which has been maintained most prominently by Henle, has enlisted the approval of even Rokitansky, and is largely received, professing to explain all inflammations, and passing by the name of "neuro-pathological," to distinguish it from the "humoral," and all other theories of inflammation. This theory may be thus briefly stated. The exciting cause of inflammation, whether an external cause, such as an injury of a part, or an internal one, such as diseased blood, acts, in the first instance, on the sensitive, centripetal, or afferent nerves of the part. These it affects as a stimulant, producing in them an excited state, which state, being conveyed to some nervous centre, is thence reflected on the centrifugal or

motor nerves of the blood-vessels of the same, or some other related, part. This reflection, however, is supposed to bring about a kind of antagonistic sympathy, such that, instead of exciting the motor forces of the blood-vessels to make them contract, it paralyses them, and is followed by their dilatation or relaxation. This dilatation being established, the exudation and other phenomena of inflammation are assumed to follow as natural, and most of them as mechanical, consequences.

The eminence of those who have supported this hypothesis makes one hesitate in rejecting it; and yet I cannot help believing it to be groundless. If we remember that parts may present some of the chief phenomena of inflammation, though they have no nerves, as the firmest tendons and articular cartilages; that the degrees of inflammation in parts bear no proportion to the amounts of pain in them when inflamed; that the severest pains may endure for very long periods with only trivial, if any, phenomena of inflammation; that the phenomena of the so-called reflex paralysis are rare, equivocal, and altogether insufficient for the foundation of a law or general principle; we may well think that there can be no sufficient ground for the invention of such an hypothesis as this. And, if we add that, even admitting the dilatation of blood-vessels as a possible consequence of the stimulus of sensitive nerves, yet the phenomena of even simple inflammation would be no necessary consequences thereof; that the varieties of inflammations would be quite unintelligible as results of similar mechanical disturbances of the circulation; and that the dilatation of blood-vessels, in any mechanical way produced, is followed by only feeble imitations of a part of the inflammatory process; then we may think that the hypothesis, if all its postulates be granted, will yet be insufficient for the explanation of the facts.

I believe that, if we would have any clear thoughts respecting the influence of the nerves in initiating inflammations, we must first receive the theory already referred to (p. 39 and 317), that a certain exercise of the nervous force is habitually and directly engaged in the act of normal nutrition. If we admit this, there can be little difficulty in believing, whatever there may be in explaining, that the perturbations of the nervous force may engender the inflammatory mode of nutrition more directly, than by first paralyzing the blood-vessels of a part. We attain nearly to a proof of this in the instances of altered nutrition adduced in a former lecture (p. 41), and in those of secretions altered, not in quantity alone, but in quality, by affections of the nervous system. It is almost inconceivable that any of the essential properties of a secretion should be changed by an alteration in the quantity or movement of the blood in a gland: yet such changes are frequently manifest in the milk, tears, urine, and sweat, under the influence of mental affections of the nervous force; and the analogies of secretion and nutrition give these cases nearly the weight of proof, in the question of the influence of the disturbed nervous force in causing inflammations.

IV. The last of the necessary conditions of normal nutrition in a part is the healthy state of the part itself; and it appears highly probable that a disturbance of this may initiate, and, in this sense be the cause of, inflammation. This is probable for many reasons; and, first, from analogy with normal nutrition. Generally, the principal conditions of nutrition are in the relative and mutual influences of the elements of the tissues and the blood. More particularly, the state of the tissues determines, at least in great measure, both the quantity and the rate of movement of the blood supplied to them; the changes of the tissues,

whether in growth or decrease, usually just preceding the adapted changes in the supply of blood (p. 69). So, we may believe, a change in a part anyhow engendered may, by altering its relation to the blood, alter its mode of nutrition; and some of the changes may produce the inflammatory mode of nutrition, together with the altered supply of blood, and other characteristic signs. I am disposed to think such changes would be especially effective, as causes of inflammation, when they ensue in the rudimental and still developing elements of the tissue; for, as it seems to be chiefly these which determine the normal supply of blood in a part, so, probably, the abnormal state of them would most affect that supply.

Secondly, we may judge the same from the analogy between inflammation and the process of repair. Certainly it is the state of the injured part, *i. e.* of its proper tissues, not of its nerves and blood-vessels, which initiates the processes of repair. Now some of these are so like those of inflammation, that they are commonly identified, and are not capable of even a refined distinction. This is, especially, the case with the articular cartilages, and the cornea.*

And thirdly, the influence of the condition of the proper tissues of a part in initiating inflammation in it, is illustrated by more direct facts; such as, that injuries of parts that have no vessels or nerves are followed by altered modes of nutrition, which are more or less exact resemblances of inflammation. Thus, *e. g.* it is in the cornea, lens, vitreous humour, and the like, after injury. In all of these, it is difficult to imagine any other cause of inflammation than

* See Dr. Redfern's researches, l. c.; and compare Mr. Bowman's account of the healing of wounds in the cornea, in his Lectures on the Parts concerned in Operations on the Eye, p. 29, with the observations already quoted from Virchow.

the altered relations between the tissue and the blood or the materials derived from it.

On the whole, therefore, I think we may conclude that inflammation may have its origin in disturbance of the normal condition of the proper tissues of a part ; in such a disturbance as may be produced by injury, or by the proximity of disease. To this source, indeed, I should be disposed to refer nearly all inflammations that originate in the direct application of local stimuli, whether mechanical or chemical. It is true, that, in most cases, the stimulus affects at once the proper elements of the part, its nerves, and its blood-vessels, so that we cannot say how much of the disease is to be ascribed to the affection of each ; but the fact that a process, resembling, so far as it goes, that of inflammation, may ensue after injury in parts that have neither vessels nor nerves, may make one believe that, in parts that have both, the inflammation depends mainly on injury, or other affection, of the proper tissue.

I have thus endeavoured to show that inflammation may take its rise, may have its proximate cause, in a disturbance of any one of the conditions of nutrition. In the examination of different cases, we find that, even while any three of the four chief conditions may be normal, yet a qualitative error of the fourth may bring in the phenomena of the inflammatory process. In the necessity of choosing pointed cases, I may seem to have implied that it is usual for inflammation not only to begin, but to be maintained, by an error in one of the conditions of nutrition : but this is improbable. Rather we may believe, that many of the excitants of inflammation may affect at once more than one of these conditions ; and, as I stated in the first lecture on the subject, it is nearly certain that in every inflammation, after a short conti-

nuance, all the conditions of the nutritive process are alike involved in error.

The following are references to some of the recent essays on inflammation, from which the reader, if he have learned the main principles concerning the disease from some of the classical works upon it,—such as those of Hunter, Thomson, Alison, or Gendrin,—may gather the best facts and guidance for future inquiry.

J. Hughes Bennett: *On Inflammation as an Anormal Process of Nutrition*. Edinburgh, 1844.—And in the first of a Series of *Clinical Lectures* published in the *Monthly Journal of Medical Sciences*, from 1850, onwards.

Bruecke (as quoted by Lebert): *Bemerkungen über Entzündung*; in the *Sitzungsberichte der Wiener Akademie*. June and July 1849.

Carpenter: In an article in the *British and Foreign Medical Review*, vol. xviii. p. 91. July 1844.

Andrew Clark: In the *Medical Gazette*, vol. xlii. p. 286; and in subsequent numbers.

Gluge: *Pathologische Histologie*, 4to. Jena, 1850.

Henle: *Rationelle Pathologie*, B. i. And in his *Zeitschrift*, especially the 2nd volume.

G. M. Humphry: *Lectures on Surgery*; in the *Provincial Medical and Surgical Journal*, 1849, and following years.

Wharton Jones: *On the State of the Blood and the Blood-vessels in Inflammation*; in *Guy's Hospital Reports*, vol. vii. 1851.

Küss (as often quoted by Lebert and Virchow): *De la Vascularité et de l'Inflammation*. 1846.

Lebert: *Physiologie Pathologique*, t. i. 8vo. 1845.—And in later works; especially in papers communicated to the *Gazette Médicale*, Juillet 15 et 22, 1852. In these he speaks of a large work on *Inflammation* which he is preparing for the press.

Redfern: *Anormal Nutrition in Articular Cartilages*. Edinburgh, 1850. And, especially, in an *Appendix to a Paper in the Monthly Journal of Medical Science*, Sept. 1851.

Reinhardt: *Ueber die Genesis der mikrosk. Elemente in den Entzündungsproducten*; in *Traube's Beiträge*, H. ii. 1846.

Rokitansky: *Pathologische Anatomie*, B. i.

Simon: *Lectures on General Pathology*. In the *Lancet*, 1850; and, collected, 8vo. London, 1850.

Travers: *Physiology of Inflammation and the Healing Process*, 8vo. 1844.

Virchow: *Essays in the 1st and 3rd, and especially in the 4th volumes of his Archiv für pathologische Anatomie. And in the 1st volume of the Verhandlungen der phys.-med. Gesellschaft in Würzburg.*

H. Weber: *Experimente über die Stase in der Froschschwimmhaut, in Müller's Archiv, H. iv. 1852.* In this essay, which I did not receive till this sheet was in the press, the author relates experiments showing that all the essential phenomena of the stagnation of blood in the capillaries and small vessels of the frog's web, after the application of stimuli, may be produced as well when the circulation has been stopped by ligature round the limb, as when the circulation is free. His observations, with others that he promises, appear likely to elucidate some of those phenomena of the movement of blood in inflamed parts for which, as I have said (p. 311), the usual mechanical explanations seem insufficient.

C. J. B. Williams: *Principles of Medicine*, 8vo. 1843 and 1848.

The process of inflammation, so far as it can be illustrated by specimens, may be fully studied in the Museum of the College, in the preparations Nos. 71 to 129, and in those which are referred to after the descriptions of these in the 1st volume of the *Pathological Catalogue*. Many of the facts relating to the state of the blood-vessels, also, are illustrated by the microscopic specimens in the same Museum. All the best illustrations of the process, in the Museum of St. Bartholomew's, may be studied by the references in the *Catalogue*, vol. i. p. xii.

LECTURE XIX.

MORTIFICATION.

By Mortification, or Sphacelus, is meant the death of any portion of the body, while the rest remains living. The term "gangrene" is commonly used in the same sense; "necrosis" for similar death of portions of bone or cartilage, or, in some recent writers, of any other tissue; "necræmia" for a corresponding death of the blood. The dead piece of tissue is called a "slough," or, if it be bone, a "sequestrum." The process of progressive dying is commonly called "sloughing," a term which is, however, also applied to the process by which a slough is separated, with the same meaning as "exfoliation" is used for the process of separating a "sequestrum" or dead piece of bone. None of these terms, however, are used unless the portions of dead tissue be visible to the naked eye. It is probable that what is ejected from the tissues in the ulcerative process is quite dead; but, so long as it is in the form of minute particles, visible only with the microscope, we speak of the disease as ulceration, not sloughing or mortification. The two processes are, however, often mingled, and can be only in general terms, and in well-marked examples, distinguished (p. 422).

It might, also, be difficult to define, in precise terms, this death of parts from some examples of their degeneration. We may doubt, sometimes, whether the degenerative

changes, imitated, as certain of them are, by chemical changes in the tissues after death, are not consequences of the total cessation of the influence of vital forces; and it seems nearly certain that degeneration of a part may proceed to its death, and is very apt to do so when, during its progress, many of the conditions of nutrition are at once interfered with. In a general view we may distinguish the degeneration of a part from its death by this,—that the degenerate part never becomes putrid, and that no process ensues for its separation or isolation, such as we can see in the case of a dead part. However degenerate a tissue may be, it either remains in continuity with those around it, or is absorbed. If the same tissue were dead, those around it would separate from it, and it would be ejected from them.

Still, it may not be pretended that degeneration and death are separated by a strong border-line. Rather, many of the instances of mortification to which I am about to refer may be read as histories of the transition from one of these conditions to the other. It will appear that a part may degenerate even to death while the rest of the body remains alive; that, as a certain diminution of the supply of arterial blood may lead to degeneration, so a greater diminution may lead to death; that, as a certain amount of inflammation has always in it a defective nutrition of the inflamed part, so, in a greater amount, the death of the same part ensues; and that the same agent may kill one portion of a tissue and inflame the portions around it. Of all such cases we might say that the local death is the extreme of degeneration.

A convenient method of studying the causes of mortification may be to divide those among them that are explicable into the direct and the indirect; *i. e.* into such as disorganize

and kill the tissues at once, and directly, though sometimes slowly, and such as do so indirectly, by depriving them of some or all of the conditions of their nutrition. Such a division, however, must not lead us to forget that, in many cases, mortification is the result of many concurring causes of both kinds.

I. In the first class we may reckon the mortifications that are the extremes of degeneration. But these can rarely be observed in unmixed examples. The more evident instances are those which result from great heat, rapidly decomposing chemical agents, and severe mechanical injury. The appearances of the dead tissues are, in these cases, modified by the presence of blood in those that are vascular, and by the blood being killed in and with them: but the state of the blood is no cause of their death; the tissues and the contained blood are killed together; and the same mode and consequences of mortification would be manifested in the non-vascular tissues.

Now, as I just suggested, it may be observed of all these destructive agents, that when they are applied in smaller measure, the effect of the injury is not to kill the part at once, but to excite an inflammation in it; and the inflammatory degeneration, thus added to the damage the part sustained from the direct effect of the injury, may lead to an indirect or secondary mortification. To this mixed origin, probably, many of the cases of traumatic gangrene may be ascribed, which are not manifest very speedily after the injury; in these we may say that a severe injury has so nearly disorganized a part, that the subsequent inflammation, with the concurrent defective nutrition, has completed its death. But, mechanical violence, heat, or chemical action, may kill a tissue at once, without the intervention of inflammation; and although, in the case of the vascular tissues, it is scarcely possible to separate the influence of the injury on

their proper elements, from that which is, at the same time; inflicted on their blood and vessels, yet we must consider the phenomena of mortification as having their seat, essentially, in the elements of the tissues. Whatever we understand as the life of a part, that life may cease; and as the life of a part is its own property, maintained, indeed, by the blood and other conditions of nutrition, yet not derived from them, so may that life cease, or, as it is said, be destroyed, without interference of the blood or any other exterior conditions of nutrition.

The immediateness of such death of a part is shown by the rapidity with which it is manifested. It is nearly instantaneous on the application of extreme heat or the strongest mechanical agents; slower after mechanical injury: but within twelve hours of the infliction of a blow the struck or crushed part may be evidently dead; there may be little or no ecchymosis, no sign of inflammation, no pain, except that which directly followed the injury, and, in the case of a bone, no apparent change of texture; but the piece of tissue is killed in the midst of the living parts; its recovery, by the re-establishment of its relations with the blood, is not possible: it cannot even be absorbed.

II. Among the instances of indirect mortification of parts, the most numerous are those in which nutrition is made impossible by some defect either (1) in the quantity, or (2), in the movement, of the blood.

Defects in the quantity of blood have been already noticed as leading to death of parts (p. 35). The following are the chief general methods of the events:—

The main artery of a part may be closed by pressure, or by some internal obstruction. Thus, sometimes, sloughing of the foot or leg follows ligature of the femoral artery for popliteal aneurism; or sloughing of part of the brain may follow ligature of the common carotid artery; and in this

case, the difference, and yet the close relation, between the death of a part and its degeneration, are well shown (compare p. 35 and 143). Thus, also, through equal internal obstruction of main arteries, sloughing may follow blows which crack the internal and middle coats, and let them fold inwards across the stream of blood :* or, the blocking of masses of fibrine, washed from the left valves of the heart, and arrested in the iliac or some other artery :† or the closure of inflamed arteries.

Portions of tissue may similarly perish when, by injury, or by progressive ulceration or absorption, all their minute blood-vessels are destroyed, and their supply of blood cut-off. Thus necrosis may follow the separation of periosteum from the surface of a bone ; when it is either violently stripped-off, or raised by effused blood, or by suppuration beneath it. Thus, also, sometimes, as an abscess approaches the surface, the thinned skin dies ; and, not like an inflamed part, but as one deprived of nutriment, it shrivels and is dried. Such sloughing is more common in perforating ulcers of the stomach or intestines ; in the course of which, when ulceration has destroyed a portion of the subperitoneal tissue and its blood-vessels, the peritoneum, hitherto fed by them, perishes, and is separated as a greyish or yellowish-white slough. In like manner, ulceration, in its progress, may so undermine or intrench a part, that at length it dies through defect of blood : thus, often, small fragments of bone are detached in strumous disease of the tarsus and other parts. And, similarly, through mere defect of blood, the centre of a tumour may slough : and here, again, is manifest the relation between the death, and the more frequent degeneration, of an imperfectly nourished part.

* Two such specimens are in the Museum of St. Bartholomew's.

† See Dr. Kirkes's essay in *Med.-Chir. Trans.*, vol. xxxv.

The effect of pressure constantly maintained on a part may be a similarly produced mortification : the part may die because its blood is pressed from it and not renewed ; but more commonly, as we see in bed-sores, inflammation ensues, and the death of the part has a double or mixed origin.

Senile gangrene, also, is without doubt, in many cases, due, in a measure, to defective quantity of blood ; but it is a more complicated example of mortification than any of the foregoing, and I shall therefore again refer to it.

I have said that parts may die through defective movement of blood. It may be present in sufficient or excessive quantity ; but it may be fatally stagnant. So far as the proper elements of the tissue are concerned, there may be little difference in their modes of death, or in their subsequent changes, in these two sets of cases ; but, as seen in the mass, the tissue dead through defect of blood is very different from that dead through stagnation of blood. In the former, we find little more than its own structures dried and shrunken or disorganized ; in the latter, the materials of abundant blood, and often of substances exuded from the congested vessels, lie mingled with the proper structures, having died with them. Hence, mainly, the differences between the mortifications distinguished as the dry and moist gangrenes ; or as the cold and hot, the white and the black, gangrenes ; these being, respectively, the technical terms for parts dead through defect, or through stagnation, of blood.

This stagnation of blood may ensue in many ways. The simplest is when a part is strangulated ; as the contents of a hernial sac may be. If the strangulation is sudden and complete, the stagnation is equally so, and the death of the part follows very quickly, with little excess of

blood in it. But, if the strangulation be less in degree, or be more slowly completed, the veins suffer more in the gradual compression than the arteries do: the vessels of the part thus become gorged with blood, admitted into them in larger quantity than it can leave them, and so mortification ensues after intense congestion or inflammation of all the tissues.*

Mere passive congestion of the vessels of a part may, in enfeebled persons, lead to mortification: but this is a rare event, for unless a part be injured, or of itself already degenerate, it may be maintained by a very slow movement of the blood.

The congestion which more commonly leads to mortification is that which forms part of the inflammatory process. It is, perhaps, to be regretted that the cases of this class should have been taken as if they were the simplest types of the process of mortification, and that the process should have been studied as an appendage, a so-called termination, of inflammation: for, in truth, the death of an inflamed part is a very complex matter; and in certain examples of it, all the more simple causes of mortification may be involved. Thus (1) the inflammatory congestion may end in stagnation of the blood, and this, as an indirect cause of mortification, may lead to the death of the blood, and that of the tissues that need moving blood for their support. But (2) a degeneration of the proper textures is a constant part of the inflammatory process; and this degeneration may itself proceed to death, while it is concurrent with defects in the conditions of nutrition. And (3) the exudation of fluid in some inflamed parts may so compress, and by the swelling so elongate, the blood-vessels, as to diminish

* This difference in the effects of constrictions of parts is particularly described by Sir B. C. Brodie: Lectures on Surgery and Pathology, p. 304.

materially the influx of fresh blood, even when little of that already in the part is stagnant.

All these, and perhaps other, conditions may concur in the mortification of an inflamed part; and their united force is commonly the more effective, by being exercised in a previously defective or degenerate condition of the inflamed tissue. The second of them, I think, has been too little considered; for by it, more than by any other event, we may understand the sloughing that ensues in the inflamed parts of enfeebled persons. The intensity of an inflammation is not, alone, a measure of the probability of mortification ensuing in its course: neither is mere debility; for we daily see inflammation without death of parts in the feeblest patients with phthisis and other diseases: rather, when mortification happens in an inflamed part, it seems to be through the occurrence of the disease in those that have degenerate tissues because of old age, or defective food or other materials for life, or through habitual intemperance. It is as if the death of the part were the consequence of the defective nutrition, which concurs with the rest of the inflammatory process, being superadded to that previously existing in the part. To the same occurrence we may, in some measure, ascribe the mortification of parts after comparatively slight injuries in the aged and intemperate: already degenerate, they perish through the addition of what, in healthier persons, would have led to only some degeneration, or to the inflammatory process, in the injured part. Such cases as these, also, stand in no distant relation to those of the mortification that ensues in inflammations after injuries. And with these we may probably class the similar effects of intense cold. Cold alone does not, in general, directly kill a part, whether in cold or in warm-blooded animals: the death that ensues appears to be the result of inflammation in the part that was cold or frozen.

Such may be the explanations of the local death that may occur in inflammation ; but, in many more cases of what appear as mortifications in inflamed parts, the death is the first event in the process, and the inflammation appears as its consequence ; or else the death and the inflammation are coincident in different parts of the same tissue. To these cases I shall again refer.

In senile gangrene we commonly find a very large number of conditions ministering to the death of the affected part. First, occurring, as its name implies, in the old, and often in those that are old in structure rather than in years, it affects tissues already degenerate, and at the very extremity and most feebly nourished part of the body. I think that, in some cases, its beginning may be when the progressive degeneration of the part has arrived at death. But, if this do not happen, some injury or disease, even a very trivial one, kills that which was already nearly dead ; as a severe injury might kill any part, however actively alive. Now, when death has thus commenced, it may in the same manner extend more widely and deeply, with little or no sign of attendant disease ; the parts may successively die, blacken, and become dry and shrivelled ; in this case, the senile gangrene is a dry one. But, more commonly, when a portion of a toe or of the foot has thus died, the parts around or within it become inflamed ; and in these, degenerate as they were already, the further degeneration of the inflammatory process is destructive ; and thus, or in this extent, by progressive inflammation and death, the gangrene, moist though senile, spreads. In either case, the extension of the gangrene is favoured by many other things ; especially by the defective muscular and elastic power, and by the narrowing or obstruction, of the degenerate arteries of the part ; by the defective movement of the blood, readily inducing a passive congestion or stagnation in parts of its

course ; by an enfeebled heart ; by the blood being, like the tissues, old, and doubtless, like them, defective ; and by the aptness of the slow-moving blood to coagulate in the vessels. All these favour the occurrence and extension of the senile gangrene : one or more of them may, sometimes, be the efficient cause of it : but my impression is, that it is essentially, and in the first instance, due, either to senile degeneration having reached its end in local death, or to the fatal superaddition of an inflammatory degeneration in a part already scarcely living.

III. In the foregoing cases, we seem able, in some measure, to explain the occurrence of mortification. But there are yet many cases in which explanation, except in the most general and vague terms, is far more difficult. In some, the local death is to be ascribed to defective quality of the blood, or to morbid materials in it. Among these, the instances of sloughing of the cornea observed in animals, and more rarely in men, whose food is deficient in nitrogen ; and those of mortifications of the extremities that have ensued after eating rye with ergot, may prove the general principle,—that certain parts, even small and circumscribed parts, may die through defects or errors of the blood which yet do not quite hinder its maintaining the rest of the body. They may, thus, be types of a large class of cases, in all of which the death of a portion of tissue seems to ensue through some wrong in the blood by which their mutual influence is destroyed ; of which cases, therefore, we may say that, as there are morbid conditions of the whole blood in which local inflammations may have their origin, so are there others in which local deaths have theirs.

Boils and carbuncles, for example, are of this kind. The sloughs, so often separated from them, are pale and bloodless ; they are not portions of tissue that have died in

consequence of stagnation of blood in them : they are white sloughs in the midst of inflamed parts. In boils, the first event of the disease may appear in the small central slough ; in such cases, the surrounding inflammation may appear to be the consequence of the slough ; but, much more probably, it is the result of a lesser influence of the same morbid condition of the blood. In the idiopathic sloughing of the cellular tissue of the scrotum, the local death is evidently, in some cases, the first event of the disease. To this class, also, of mortifications in consequence of morbid conditions of the blood, we must refer, I presume, the cases of hospital gangrene ; those of the most severe and most rapidly extending traumatic kind ; those of the sloughings of mucous membranes and other parts, that sometimes ensue in typhus, scarlet fever, and other allied diseases, when they deviate from their ordinary course ; the sloughing of syphilitic sores, and many others.

Lastly, we may enumerate among the causes of death of parts the defect of nervous force : but the examples of this have been related in a former lecture (p. 43) ;* and it only needs, perhaps, to be said here that this defect may mingle its influence with many other more obvious causes of mortification. When a part is severely injured, its nerves suffer proportionate violence, and their defective force may add to the danger of mortification ; in the old, not the blood, or the tissues alone, are degenerate, but the nervous structures also ; and defective nervous force may be, in them, counted among the many conditions favourable to the senile gangrene ; and so, yet more evidently, the

* There are yet many cases which I can neither explain nor classify ; such as those from the effects of animal poisons, malignant pustule, peculiar gangrenes of the skin, and many others. On all these, and, indeed, on the whole subject of mortifications, the reader will find no work that he can study with so much profit as the lectures of Sir B. C. Brodie.

s loughing of compressed parts is peculiarly rapid and severe when those parts are deprived of nervous force by injury of the spinal cord, or otherwise.

While the causes of mortification are so manifold ; while it is, in fact, the end of so many different affections, it is not strange that the appearances of the dying and dead parts should be extremely various. The changes in them (independent of those produced by great heat, caustics, or other such disorganizing agents) may be referred to three chief sources : namely, (1) those that ensue in the dying and dead tissues ; (2) those in the blood, dying with the tissues, and often accumulated in them in unnatural abundance ; (3) those which are due to the inflammation or other disease or injury, which has preceded the death of the part, and of which the products die with the tissue and the blood, and change with them after death.

But, though we may thus classify the morbid changes in mortified parts, yet we can hardly enumerate the varieties which, in each class, are due to the previous diseases of the part, or to external conditions ; such as differences of temperature, of moisture, and others. All the chemical changes which, in life, are repaired and unobserved, are here cumulative ; all those external forces are now submitted to, which, while the parts were living, they seemed to disregard ; so exactly were they adjusted in counter-action. It is, therefore, only in typical examples that mortifications can be well described. The technical terms applied to them have been already mentioned ; and "dry" and "moist" signify the chief differences dependent on the quantity of blood and of inflammatory products in the dead parts. "Dry gangrene" is usually preceded by diminished supply of blood to the part ; "moist or humid gangrene" by increased supply, and often by inflammation ; the former,

more slowly progressive is usually a "chronic," or, as some have called it, "cold gangrene;" the latter an "acute or hot gangrene."

Among the examples of mortification due to defective supply of blood, and therefore classed as dry gangrenes, great differences of appearance are due to the degrees in which the dead parts can be dried. As it may be observed in the integuments of the leg, for example, it may be noticed that, in the first instance, the part about to die appears livid, or mottled with various dusky shades of purple, brown, or indigo, through which it seems to pass as its colours change from the dull ruddiness of stagnant or tardy blood towards the blackness of complete death. It becomes colder, and gradually insensible; its cuticle separates, and is raised in blisters by a serous or more or less blood-coloured or brownish fluid. Then, as the cuticle breaks and is removed, the subjacent integument, hitherto kept moist, being now exposed to the air, gradually becomes drier; withering, mummifying, becoming dark brown and black, having a mouldy rather than a putrid smell; it is changed, as Rokitansky says,* like organic substances decomposed with insufficient moisture and with separation of free carbon. Such are the changes often seen in the dry senile gangrene, and in that which may follow obstruction of the main arteries in young persons: but, very generally, as the interior parts of the limb cannot be dried so quickly as the exterior, and are, perhaps, less completely deprived of their supply of blood, they, or portions of them, become soft and putrid, while the integuments become dry and musty.

In other cases of mortification similarly caused, the dead parts, though deprived of blood, cannot become dry; either they are not exposed to air, or they are soaked with fluid

* Pathologische Anatomie, i. p. 257.

exuded near them. In these instances the sloughs may be dark ; but they are commonly nearly white ; and hence one of the grounds for the technical distinction of white and black gangrene. Such white sloughs are commonly seen when the peritoneum mortifies, after being deprived of blood by ulceration gradually deepening in the walls of the digestive canal ; and, sometimes, in the integuments over an abscess, when the cuticle has not previously separated. If this have happened, the dead and undermined integument may become dry and horny ; but if the cuticle remain, it is commonly white, soft, and putrid.

The typical examples of the moist gangrene are those which occur in inflamed parts, and chiefly in consequence of inflammation, and to which, therefore, the names of "acute" and "hot" gangrene have been applied. We must not reckon among these the cases in which the death of the part precedes, or has a common origin with, the inflammation ; for in these, as in boils, carbuncles, and hospital gangrene, the slough is commonly bloodless, white or yellowish-, or greyish-white, and, if it were not immersed in fluid, would probably be dry and shrivelled. The mortification that occurs during inflammation, and as in part a consequence of it, finds the tissues full of blood, and often of exuded lymph and serum, which all perish with them.

If such a process be watched in an inflammation involving the integuments, or in senile gangrene rapidly progressive with inflammation, or, as in the most striking instance, in the traumatic gangrene following a severe injury of a limb, the parts that were swollen, full red, and hot, and perhaps very tense and painful, become mottled with overspreading shades of dusky brown, green, blue, and black. These tints, in mortification after injuries, may, sometimes, seem at first like the effects of ecchymoses ;

and often, after fractures of the leg, a further likeness between the two is produced by the rising of the cuticle in blisters filled with serous or blood-coloured fluids at the most injured parts. But the coincident or quickly following signs of mortification leave no doubt of what is happening. The discoloured parts become cold and insensible, and more and more dark, except at their borders, which are dusky red; a thin, brownish, stinking fluid issues from the exposed integuments; gas is evolved from similar fluids decomposing in the deeper seated tissues, and its bubbles crepitate as we press them; the limb retains its size or enlarges, but its tissues are no longer tense; they soften as in inflammation, but both more rapidly and more thoroughly, for they become utterly rotten. At the borders of the dying and dead tissues, if the mortification be still extending, these changes are gradually lost; the colours fade into the dusky red of the inflamed but still living parts; and the tint of these parts may afford the earliest and best sign of the progress towards death, or the return to a more perfect life. Their becoming more dark and dull, with a browner red, is the sure precursor of their death; their brightening and assuming a more florid hue is as sure a sign that they are more actively alive. Doubtless the varieties of colour indicate, respectively, the stagnation and the movement of the blood in the parts which, thus situated, may, according to the progress of their inflammation, be added to the dead, or become the apparatus of repair.

The interior of a part thus mortified corresponds with the foregoing description. All the softer tissues are, like the integuments, rotten, soft, putrid, soaked with serum and decomposed exuded fluid; ash-coloured, green, or brown; more rarely blue or black; crackling with various gases extricated in decomposition. The tendons and articular cartilages in a mortified limb may seem but little

changed; at the most they may be softened, and deprived of lustre. The bones appear dry, bloodless, and often like such as have been macerated and bleached; their periosteum is usually separated from them, or may be easily and cleanly stripped off. But these harder and interior parts of a limb either die more slowly, or more slowly manifest the signs of death, than do those around them; for, not only do they appear comparatively little changed, but, often, when all the dead soft parts are completely separated from the living, the bone remains continuous, and its medullary vessels bleed when it is sawn-off. Usually, also, after complete spontaneous separation of the mortified part of a limb, the stump is conical; the outer parts of it having died higher up than the parts in its axis.

Another appearance of mortified parts, characteristic of a class, is presented after they have been strangulated. I have mentioned the difference which in these cases depends on whether the strangulation have been suddenly complete, or have been gradually made perfect (p. 458). In the former case, the slough is very quickly formed, and may be ash-coloured, grey, or whitish, and apt to shrivel and become dry before its separation. In the latter case, as best exemplified in strangulated hernia, the blood-vessels become gradually more and more full, and the blood more dark, till the walls of the intestine, passing through the deepest tints of blood-colour and of crimson, become completely black. Commonly, by partial extravasation of blood, and by inflammatory exudation, they become also thick, firm, and leathery, a condition which materially adds to the difficulty of reducing the hernia, but which is generally an evidence that the tissues are not dead; for when they are dead, they become not only duller to the eye, but softer, more flaccid and yielding, and easily torn, like the rotten tissues of other mortified parts. The canal, which was before cylin-

drical, may now collapse; and now, commonly, the odour of the intestinal contents penetrates its walls.

I have spoken of the death of the blood as coinciding with that of the part in whose vessels it is enclosed. Very commonly, when this happens, coagulation of blood ensues in the vessels for some distance above, *i. e.* nearer to the heart than, the mortified parts. Hence, as it has been often observed, no bleeding may occur from even large arteries divided in amputations above the dead parts of sloughing limbs.

It remains now to speak of the phenomena which ensue when gangrene ceases, and of which the end is, that the dead parts are separated from the living.

As for the dead parts, they only continue to decompose, while, if exposed to a dry atmosphere, they gradually shrivel, becoming drier and darker. But more important changes ensue in the living parts that border them. The first change that occurs in this process (the whole of which may be studied as the most remarkable instance of the adaptation of disease for the recovery of health), the first indication of the coming reparative process, is a more decided limitation and contrast of colour at the border of the dying part. As we watch it in the integuments, the dusky redness of the surrounding skin becomes more bright, and paler, as if mingled with pink rather than with brown; and the contrast reaches its height when, as the redness of the living part brightens, the dead whiteness or blackness of the slough becomes more perfect. The touch may detect a corresponding contrast: the living part, turgid with moving blood, feels tense and warm; the dead part is soft, or inelastic, cold, and often a little sunken below the level of the living. These contrasts mark out the limits of the two parts: they constitute the "line of demarcation" between them.

The separation of the dead and living parts, which remain continuous for various periods after the mortification has ceased and the line of demarcation is formed, is accomplished by the ulceration of the portions of the living tissues which are immediately contiguous to the dead. At this border, and (in parts that are exposed) commencing at the surface, a groove is formed by ulceration, which circumscribes and intrenches the dead part, and then, gradually deepening and converging, undermines it, till, reaching its centre, the separation is completed, and the slough falls or is dislodged by the discharge from the surface of the ulcerated living part. Commonly, before the border of the integuments ulcerates, it becomes white and very soft; so that, for a time, a dull white line appears to divide the dead and living parts.

Closely following in the wake of this process of ulceration is one more definitely directed towards repair. As the ulcerated groove deepens day by day around and beneath the dead part, so do granulations rise from its surface; so that, as one might say, that which was yesterday ulcerating is to-day granulating; and thus, very soon after the slough is separated, the whole surface of the living part, from which it was detached, is covered with granulations, and proceeds, like an ordinary ulcer, towards healing.

There is, I believe, nothing in the method of thus separating a dead part, thus "casting-off a slough," which is not in conformity with the general process of ulceration. When a portion of the very interior substance of an organ dies, and is separated, there may be doubt, as in some nearly corresponding cases of ulceration (p. 420), whether the clearing away of the living tissue adjacent to it be effected by absorption or by disintegration, and mingling with the fluid in which, after separation, the dead piece lies. We may have this doubt in such cases as the sloughing of

subcutaneous tissue in carbuncles not yet open, or in phlegmonous erysipelas, or in the cases of internal necrosis ; in which, without any external discharge, pieces of dead tissue are completely detached from the living tissue around them : and I do not know how such doubt can be solved. But the separation of superficial or exposed dead parts might be studied as the type of the ulcerative process, of which, indeed, it is in disease the usual beginning (see p. 422), and with the more advantage, because the sloughing of parts of limbs affords illustrations of the process in tissues in which it very rarely happens otherwise. Especially, it shows the times at which, in different tissues, ulceration may ensue, and hereby the times during which, under similar conditions of hindered nutrition, the tissues may severally maintain life.

The process which I have exemplified by the mortification of soft parts has an exact and instructive parallel in necrosis or mortification of bone ; but there are in the phenomena of necrosis some things which deserve a brief mention because of their clearly illustrating the general nature of the process following the death of a part.

Thus (1) we find in bones a permanent evidence of the increase of vascularity of the tissues around a dead part ; for, in specimens of necrosis, the bone at the border of the dead piece has always very numerous and enlarged Haversian canals. (2) We may often see that the reparative process, on the borders of the living part, keeps pace with, or rather precedes by some short interval, the process by which the living and the dead are separated : for new bone is always formed in and beneath the periosteum at the border of the living bone, while the groove around the dead piece is being deepened, or even before its formation has commenced. (3) Instances of necrosis show

some of the progressive changes that lead to the formation of the groove of separation. The bone at the very junction of the living and the dead becomes, first, soft and ruddy, as an inflamed bone does. Its earthy matter, as Mr. Hunter described, is first (by absorption, as we must suppose) removed in larger proportion than its animal basis. This basis remains, for a time, connecting the dead and the living bone, both of which, retaining their natural hardness, appear in strong contrast with it; but soon this also is removed, and the separation is completed. (4) From some cases of necrosis, also, we obtain evidence on a question about the removal of dead tissue. It is asked whether dead tissue may not be absorbed, and so removed. Examples of necrosis show that, in the large majority of cases, the separation of dead bone is accomplished entirely by the ulceration or absorption of the living bone around it; but that, in certain cases, especially in those in which pieces of bone, though dead, remain continuous with the living, the dead bone may be in part absorbed, or otherwise removed, not indeed in mass but after being disintegrated or dissolved.* (5) In cases of necrosis we find the best examples in which, apparently through want of vital force, the dead and living parts remain long united and continuous. A piece of dead bone,

* Such cases are recorded by Mr. Stanley, in whose Treatise on Diseases of the Bones I need hardly say that all the phenomena of necrosis are much more fully described than they are here. The possibility of the absorption of dead bone seems amply proved by cases (one of which I watched while it was under his care) in which portions of pegs of ivory, driven like nails into bones, to excite inflammation for the repair of ununited fractures, have been removed. The absorption, I say, seems amply proved; but the method of it is made, by the same observations, more difficult than ever to explain; for only those portions of the ivory that were imbedded in the bone were absorbed; the portions that were not in contact with bone, though imbedded in granulations or pus, were unchanged.

proved to be dead by its blackness, insensibility, and total absence of change, may remain even for months connected with living bone: and no process for its separation is established till the patient's general health improves. (6) Lastly, in the death of bone, we may see a simpler process for the separation of the living tissues than that which is accomplished by ulceration. In superficial necrosis, the periosteum, at least in those parts in which its own tissue does not penetrate, so as to be continuous with, that of the bone, separates cleanly from the surface of the dead bone, retaining its own integrity and smoothness, and leaving the bone equally entire and smooth. No observations have yet been made, I believe, which show how this retirement of one tissue from another is effected, or how the blood-vessels that pass from one to the other are disposed of. Another method of separation without the ulcerative process is observed when teeth die, especially in old persons. Their sockets enlarge, apparently by mere atrophy or absorption of their walls and margins; so that the teeth-fangs are no longer tightly grasped by them, but become loose, and project further from the jaw.

LECTURE XX.

SPECIFIC DISEASES.

It would be far beyond the design of these lectures, intended only for the illustration of the General Principles of Pathology, in its relations with Surgery, if I were to enter largely on the consideration of the diseases named specific. It will be sufficient, I hope, and certainly will more nearly correspond with the rest of my plan, if I describe the general features of specific diseases, and their general import; and if I point out, though only in suggestions, how we may more effectually study them; how, many things relating to them, which we are apt to dismiss with words, may be subjects of deeper, and perhaps useful, thought.

The term "specific disease," as employed in common usage and in its most general sense, means something distinct from common or simple disease. Thus, when a "specific inflammation" or a "specific ulcer" is spoken of, we understand that these present certain features in which they differ from what the same person would call a "common" or a "simple inflammation" or "ulcer." The specific characters of any disease, whether syphilis or hydrophobia, gout or rheumatism, typhus, small-pox, or any other, are those in which it constantly deviates from the characters of

a common or simple disease of the same general kind.* Our first inquiry, therefore, must be,—what are these common diseases, which we seem to be agreed to take as the standard by which to measure the specific characters of others?

I believe that, in relation to inflammatory diseases and their consequences, our chief thoughts concerning such standards for comparison are derived from the affections which follow injuries by violence, or by inorganic chemical agents, by heat, or any other commonly applied causes of disease. When such a blow is inflicted as kills a portion of the body, its consequences afford a standard with which we may compare all other instances of mortification and sloughing; and when, among these, we find a certain number of examples which differ, in some constant characters, from this standard, we place them, as it were, in a separate group, as examples of a specific disease. Or, again, when a part is submitted to such pressure as leads to its ulceration, we regard the disease as a common, simple, or standard ulcer; and by their several constant differences from it, and from one another, we judge of the various ulcers which we name specific. In like manner, our standard of common or simple inflammation seems to be derived from the processes which follow violence, the application of heat, the lodgment of foreign bodies, or the application of

* It may not be unnecessary to guard some students at once from the suspicion, which the terms in common use may suggest, that there is a correspondence between the species of diseases and those of living creatures as studied in natural history. There is really no likeness, correspondence, or true analogy between them; and if nosological systems, framed after the pattern of those of zoology, lead to the belief that they have any other resemblance than that of the modes of briefly describing, and of grouping double names, they had better be disused.

certain chemical stimulants. And the standard of common or simple fever is that which ensues in a previously healthy man, soon after he has received some such local injury as any of these agents might produce. Now, it is very reasonable that we should take these as the best examples of common or simple disease; the best, I mean, for comparison with those that may be called specific. For not only can we produce some of these common diseases when we will, and study them experimentally, but they manifestly present disease in its least complicated form; least specified by peculiarities either in its cause or in its subject. Only, in adjusting our standards of disease from them, it is necessary that we should take the characters presented by all or by the great majority of instances; since the consequences of even the simplest mechanical injuries are apt to vary according to the peculiar constitution of the person injured.

The terms simple and specific are sometimes applied, in equal contradistinction, to tumours. Here we have no such standard of accidental or experimental disease; but that which seems to be taken as the measure of simplicity in a tumour, is the conformity of its structure with some of the natural parts of the body. The more a tumour is like a mere overgrowth of some natural structure, the more "simple" is it considered; and the specific characters of a tumour are chiefly those in which, whether in texture or in mode of life, it differs from the natural parts. When, however, a tumour is diseased,—for instance, when a cancer ulcerates,—the specific characters of the ulcer are estimated by comparison with the characters of common or simple ulcers.

Such are, in the most general terms, the standards of common or simple diseases. The title "common" applied to them is, in another sense, justified by the features which they present being, for the most part, common to them and to the specific diseases. For, in the specific diseases, we

do not find morbid processes altogether different from those which are taken as standards, but only such processes as are conformed with them in all general and common features, but differ from them by some modification or addition. In other words, no specific disease is entirely peculiar or specific; each consists of a common morbid process, whether an inflammation, an ulceration, a gangrene, or any other, and of a specific modification or plan in some part thereof.

Let us now see what these modifications, these specific characters, are; and here, the history of tumours being reserved to the next volume, let me almost limit the inquiry to a comparison of the inflammatory affections of the two kinds, and select examples from only such as are, by the most general consent, called specific; as syphilis, gout, rheumatism, the eruptive fevers, and the like.

1. Each specific disease constantly observes a certain plan or construction in its morbid process; each, as I just said, presents the phenomena of a common or simple disease, but either there is some addition to these, or, else, one or more of these is so modified as to constitute a specific character; a peculiarity by which each is distinguished at once from all common, and from all other specific, diseases. Thus, we see a patient with, say, two or three annular or crescentic ulcers on his legs; and, if we can watch these, they are, perhaps, healing at their concave borders at the same time as they are extending at their convex borders. Now, here are all the conditions that belong to common ulcers; and, in different instances, we might find these ulcers liable to the variations of common ones, as being more or less inflamed or congested, acute or chronic, progressive or stationary; but we look beyond these characters, and see, in the shape and mode of extension of these ulcers, pro-

perties which are not observed in common ones ; we recognise these as specific characters ; we may call the ulcers specific ; or, because we know how commonly such ulcers occur in syphilis, and how rarely in any other disease, we call them syphilitic ulcers, and treat them with iodide of potassium, or some other specific ; that is, specially curative medicines. Another patient has, say, numerous small, round, dusky, or light brownish-red, slightly elevated patches of inflammation of the surface of his skin ; on many of them there are small, dry, white scales ; and some of them may be arranged in a ring. Here, again, are the common characters of inflammation : but they are peculiarized in plan and tint of redness, and in general aspect ; and because of these we regard the disease as specific, and call it psoriasis, and, because of the additional peculiarity of dusky or coppery redness, and of the annular or some other figurate arrangement, we suspect that it is syphilitic psoriasis. Or, we look through a series of preparations of ulcerated intestines ; and we call one ulcer simple or catarrhal, another typhous, another dysenteric, a fourth tuberculous : all have the common characters of ulcers ; but these are, in each, peculiarly or specifically modified in some respect of plan ; and the modifications are so constant that, without hearing any history of the specimens, we may be sure of all the chief events of the disease by which each ulcer was preceded. Or, among a heap of diseased bones, we can select those whose possessors were strumous, rheumatic, syphilitic, or cancerous ; finding in them specific modifications of the results of some common disease, such as new bone, *i. e.* ossified inflammatory deposits, arranged in peculiar methods of construction, or at particular parts ; or ulcers of peculiar shape and peculiar method of extension.

I need not cite more examples of the thousand varieties

in which the common phenomena of disease are modified in specific diseases. In some, the most evident specific characteristics are peculiar affections of the movement of the blood, as in the cutaneous erythemata; in some, affections of certain parts of the nervous centres, as in tetanus, hydrophobia, and hooping-cough; in some, peculiar exudations from the blood, as in gout and the inoculable diseases; in some, peculiar structures formed by the exuded materials, as in variola, vaccinia, and other cutaneous pustular eruptions; in some, destructions of tissues, as in the ulcers of syphilis, the sloughs of boils and carbuncles; in some, peculiar growths, as in cancer; in some, or indeed in nearly all, peculiar methods of febrile general disturbance; but, in each of all the number, the phenomena admit of distinction into those of common disease, and those in which such disease is peculiarly modified, or by which, if I may so say, it is specified.

The morbid process thus modified may be local or general. Usually, in specific diseases, both local and general morbid processes are concurrent, and both are, in a measure, specific; but, although we can scarcely doubt that there is in every case an exact and specific correspondence between the two, yet, at present, the general or constitutional affections of many different specific diseases appear so alike, that we derive our evidence of specific characters almost entirely from the local part of the disease. The premonitory general disturbances of the exanthemata, or the slighter disorders preceding cutaneous eruptions, are, severally, so alike, that, except by collateral evidence, we could seldom do more than guess what they portend; their specific modifications of common general disturbance are too slight for us to recognise them with our present knowledge and means of observation.

2. Observing the causes of specific diseases, we find that

some, and these the most striking examples of the whole class, are due to the introduction of peculiar organic compounds,—morbid poisons, as they are generally called,—into the blood. Such are all the diseases that can be transmitted by inoculation, contagion, or infection. All these are essentially specific diseases; each of them is produced by a distinct substance, and each produces the same substance, and by a morbid process separates it from the blood. In most of these, also, as well as in many of which the causes are internal and less evident, the local phenomena are preceded by some affection of the whole economy: the whole blood seems diseased, and nearly every function and sensation is more or less disturbed from its health; the patient feels “ill all over,” before the local disease appears; *i. e.* before the more distinct and specific morbid process is manifest in the place of inoculation or in some other part. Herein is a very general ground of distinction between the specific and the simple or common diseases: in the latter, the local phenomena precede the general or constitutional; in the former, the order is reversed. We might, indeed, expect this to be a constant difference between the two; and perhaps it is so; for though many exceptions to any rule founded on it might be adduced, yet these may be ascribed to the unavoidable sources of fallacy in our observations. Thus, every severe injury, every long-continued irritation, excites at once both local and general disease; and the latter may be evident before the former, and may not only modify it, but may seem to produce it. On the other hand, the insertion of certain specific poisons, *e. g.* that of the venom of a serpent or an insect, gives rise so rapidly to specific local disease that this seems to precede all constitutional affection.

Notwithstanding such exceptions as these are, or seem to be, this contrast between specific and common diseases, in

regard to the order in which the local and the constitutional symptoms arise, is so usual that the terms specific and constitutional are often employed as convertible terms in relation to disease. But this is not convenient; for some specific diseases are, or become, local; and some constitutional diseases are not specific.

3. A character very generally observed in specific diseases is an apparent want of proportion between the cause and the effect. In common disease, one might say that, on the whole, the quantity of local disease is in direct proportion to the cause exciting it,—whether violent injury, heat, poison, or any other. Numerous exceptions might be found, but this is, on the whole, the rule.* In specific diseases there is no appearance of such a rule: we cannot doubt its existence, but it is lost sight of. Thus, in small-pox, measles, hydrophobia, or syphilis, the severity of the disease is not, evidently, proportionate to the cause applied; a minimum of inoculated virus engenders as vast a disease as any larger quantity might.

4. I have said that there is generally a correspondence between the local and the constitutional characters of a specific disease: but this is only in respect of quality: in respect of quantity there is often such a want of correspondence between the two as we rarely or never see in common diseases. In general, the amount of common inflammatory fever after an operation bears a direct proportion to the injury, and the amount of hectic fever to the

* I am tempted to say here, that, in pathology, we must admit the existence of many rules or laws the apparent exceptions to which are more numerous than the plain examples of them. This, however, is not enough to invalidate the truth of the laws; it could scarcely be otherwise in the case of laws, the exact observance of which requires the concurrence of so many conditions as are engaged in nearly all the phenomena studied in pathology.

quantity of local disease, (here, again, are numerous exceptions, but this is the rule); but in specific diseases it is far otherwise. In syphilis and cancer, the severest defects or disturbances in the whole economy may coexist with the smallest amounts of specific local disease; and, as Dr. Robert Williams* has well said, "It may be laid down as a general law, that when a morbid poison acts with its greatest intensity, and produces its severest forms of disease, fewer traces of organic alterations of structure will be found than when the disorder has been of a milder character."

5. To specific diseases belongs all that was said, in former Lectures (p. 18, e. s.), of the symmetrical diseases, and of seats of election: such phenomena occur in degenerations, but, I think, in no common diseases.

6. The local process of a specific disease of nutrition is less apt than that of a common one to be nearly limited to the area in which, in the first instance, the cause of disease was applied. Specific diseases are peculiarly prone to spread, that is, to extend their area. They also, among the diseases of nutrition, are alone capable of being erratic, *i. e.* of disappearing from the part in which they were first manifest, while extending thence through other parts continuous with it; and they alone are capable of metastasis, *i. e.*, of suddenly ceasing in one locality, and manifesting themselves, with similar local phenomena, in another.

7. In all the particulars mentioned in the last preceding, and in some of the earlier, paragraphs, specific diseases manifest a peculiar character in that they seem capable of self-augmentation; no evident fresh cause is applied, and yet the disease increases: witness the seemingly spontaneous increase of manifest local disease in secondary and

* Elements of Medicine, vol. i. p. 12.

tertiary syphilis, or in the increasing eruption of eczema or of herpes, or the extension of a carbuncle, or the multiplication of secondary cancers.

8. Specific diseases alone are capable of transformation or metamorphosis. As we watch a common disease, its changes seem to be only those of degree; it appears increasing or declining, but is always the same and a continuous disease. But in many specific diseases we see changes in quality or kind, as well as in quantity. In syphilis, for example, a long series of diseases may occur as the successive consequences of one primary disease different from them all. They are all, in one sense, the same disease, as having a single origin: but it is a disease susceptible of change in so far as it manifests itself, at different times, not only in different parts, but in different forms in each, and in forms which are not wholly determined by the nature of the tissue affected. The successive phenomena of measles, scarlet fever, and many others, may, I think, be similarly expressed as metamorphoses or transformations of disease.

9. A similar transformation of specific diseases may take place in their transference from one person to another, whether by inheritance,* or by infection, or contagion. A parent with one form of secondary syphilis may have a child with another form; the child of a parent with scirrhus cancer may have an epithelial, a colloid, or a medullary cancer: the inoculation of several persons with the matter from one primary syphilitic sore may produce different forms of the primary disease and different consecutive phenomena; the same contagion of small-pox, measles, or scarlet-fever may produce in different subjects all the modi-

* It might seem as if none but specific diseases could be hereditary; but many tumours are so which we cannot well call specific: such as the cutaneous cysts or wens, and fatty and cartilaginous tumours.

fications of which those diseases are severally capable ; the puerperal woman, or the patient who has sustained a severe accidental or surgical injury, may modify, or, as it were, colour with the peculiarities of her own condition, whatever epidemic or other zymotic disease she may incur.*

10. Lastly, time is a peculiarly important condition in many of the specific diseases. If we except the period of calm or incubation, which usually occurs between the infliction of an injury and the beginning of an evident reparative process, a period of which the length is, in general, proportionate to the severity of the injury, there are few of the events of common diseases that are periodic or measurable in time ; there are none that are regularly intermittent or remittent ; none that can be compared, for regularity, with the set times of latency of the morbid poisons of the eruptive fevers, or the periods in which they run their course, or change their plan or chief place of action. Neither are there, in common diseases, any periods of latency so long as those which elapse between the application of the specific cause, and the appearance of its specific effect, in the eruptive fevers, tetanus, or hydrophobia.

Such, briefly, are the chief general characters of the diseases which are commonly named specific, or described as having something specific in their action. In some of them, chiefly such as depend on distinct morbid poisons, whether miasma, or virus, or matter of contagion, all these characters may be observed ; and these are the best types of the class. In others, part only of the same characters concur. I do not pretend to define the exact boundary of what should be called specific, and what common, in dis-

* See Carpenter ; Br. and For. Med.-Chir. Review, Jan. 1853, quoting from Simpson, in Monthly Journ. of Med. Sc. vol. xi. and xiii.

eases ; but it seems reasonable that any disease, in which the majority of the characters just enumerated are found, should be studied as one of the class, and that its phenomena should be interpreted, if possible, by the rules, or by the theory, derived from the more typical members of the same class.

The theory of specific diseases, in its most general terms, is, that each of them depends on a definite and specific morbid condition of the blood ; that the local process in which each is manifested is due to the disorder produced by the morbid blood in the nutrition of one or more tissues ; and that, generally, this disorder is attended with the accumulation, and leads to the discharge, or transformation, of some morbid constituents of the blood in the disordered part. It is held, also, that, in some specific diseases, the morbid condition of the blood consists in undue proportions of one or more of its normal constituents ; and that in others, some new morbid substance is added to or formed in the blood. In either case, the theory is, that the phenomena of each specific disease depend chiefly, and in the first instance, on certain corresponding specific materials in the blood : and that if characteristic morbid structures be formed in the local process, they are organs in which these morbid materials are incorporated.

Now in regard to certain diseases, such as some of those that can be communicated by inoculation, these terms are scarcely theoretical ; they may rather be taken as the simplest expressions of facts. For example (as I have already said, p. 441) in either syphilis, vaccinia, glanders, or small-pox, especially when produced by inoculation, we have demonstration (1) of a morbid condition of the blood ; (2) of the definite and specific nature of that condition, in that it is, and may be at will,

produced by the introduction of a definite substance into the blood, and manifests itself in a local disease which, within certain limits, has constant characters; and (3) of the same substance being accumulated and discharged, or for a time incorporated in the morbid structures, at the seat of the local disease. And it seems important to mark, that all which is thus seen in some specific diseases, and is assumed for the explanation of others, is consistent with facts of physiology; especially with those referred to in a former Lecture (p. 27, e. s.), as evidences, that certain normal organs of the body are formed in consequence of the presence of materials in the blood, which, in relation to them, might be called specific, and which they, in their formation, take from the blood and incorporate in their own structures.*

The proof of the theory of specific diseases is scarcely less complete for all those that are infectious or contagious, but cannot be communicated by inoculation—such as typhus, measles, erysipelas; and scarcely less for those which are neither infectious nor contagious, but depend, like cholera and ague, on certain materials which are introduced into the blood, and produce uniform results, though they are not

* Abundant illustrations of the same general laws, of both healthy and morbid formation of structures incorporating specific materials from the blood, are supplied by the action of medicines whose operation ensues in only certain organs. Dr. Robert Williams (l. c. p. 8) has justly said, "The general laws observable in the actions of morbid poisons are, for the most part, precisely similar to those which govern medicinal substances, or only differ in a few minor points." The subject is too extensive for discussion here. It is admirably treated by Mr. Simon in his Lectures on Pathology; the work, which, together with that of Dr. Robert Williams, may be studied with more profit, in relation to all the subjects of this Lecture, than any I have yet read.

proved to exist in the products of the morbid processes. For other diseases, classed or usually regarded as specific, such as gout, rheumatism, carbuncle, boil, the various definite, but not communicable, cutaneous eruptions, hydrophobia, tetanus, and many more, the evidences of the theory are less complete. Yet they seem not insufficient; while we have, in many of these affections, proofs of the accumulation and separation of morbid substances at the seats of local disease, and while, in all, the chief phenomena are in close conformity with those of the diseases which are typically specific. Relying on the similarity of all the members of the group of specific diseases, on the sufficiency of the terms of the theory for the expression of the facts concerning them all, and on the evidences more or less complete which each of them supplies for its truth, we seem justified in adopting the same theory for them all.

But, now, if we may hold this theory to be true for some specific diseases, and not unreasonable for the rest, let us see how, in its terms, we can explain or express the chief characters of these diseases; such as their periodicity, metastases, and metamorphoses, the apparent increase of the specific substance in the blood, and the others just enumerated. This may be done while tracing the probable history, or, as I would call it, the life, of the morbid material in the blood, and in the tissues.*

Specific morbid materials, or at least their chief constituents, may enter the body from without, by inoculation, contagion, or infection; or they may be formed in the

* Several of the characters of specific diseases are already explained, in the terms of this theory, in the earlier Lectures: namely, their specific forms and constructions (pp. 27, 34, 63); symmetry and seats of election (pp. 18, 21, 441, e. s.); extension and errantry (p. 20, note).

blood, or added to it, within the body: in other words, some morbid materials are inserted, others are inbred, in the blood; with some, probably, both modes of introduction are possible. Doubtless, an important difference is thus marked between two chief groups of the specific diseases: but it is not within my present purpose to dwell on it; for only one general history can as yet be written for the whole class of morbid materials on which the specific diseases depend: and, although this may be best drawn from the instances of those that are derived from without, *i. e.*, from such as are called morbid poisons, yet it would probably be as true, in all essential features, for those that are inbred.

When a morbid poison is inoculated,—for example, when the matter from a syphilitic sore, or from a vaccine vesicle, is inserted in the skin,—it produces a specific effect both on the tissue at the place of insertion, and on the blood, as soon as it, or any part of it, is absorbed: in other words, it produces both a local and a constitutional change; and in both these effects its history must be traced.

I. First, respecting the local change; of which, with another design, I have already spoken (p. 443). It is not proved by anything that can be seen immediately, or even within one or two days after the inoculation. The place of inoculation remains, for a time, apparently unaffected: and yet that a peculiar change is being wrought in it is clear, for it presently becomes the seat of specific disease, the materials of which disease are supplied by blood that nourishes healthily all other parts, even such parts as may have received common injuries at or near the time of the inoculation. The inoculated part, therefore, is not merely injured, but is peculiarly altered in its relation to the blood, which now nourishes it differently from all the rest of the body. The change of the blood is proved, if not by general febrile

or other disturbance, yet by the specific character of the presently ensuing disease, and by the consecutive secondary disease, or by consecutive immunity from later disease of the same kind.

If further proof be needed of the specific local change produced in the inoculated part, it may be furnished by the analogy of the more visible effects of certain animal poisons,—such as those of venomous serpents and insects. None of these appear to be simple irritants; the consequences of their insertion are not like simple inflammations, but are peculiar, and constant in their peculiarities. The bite of a bug or a flea will not, I hope, be thought too trivial for an illustration.

In less than a minute after the bite, the bitten part begins to itch; and quickly after this, a wheal or circumscribed pale swelling, with a nearly level surface and a defined border, gradually rises and extends in the skin. It seems to be produced by an cedema of a small portion of the cutis at and around the bite; it is not a simple inflammatory swelling; it is, from the first, paler than the surrounding skin, which may be healthy or slightly reddened by afflux of blood: and the contrast between them becomes more striking, as the surrounding skin becomes gradually redder, as if with a more augmented fulness of the blood-vessels. Thus, for some minutes, the wheal appears raised on a more general, and less defined, vascular swelling of the surrounding and subjacent tissues; but, after these minutes, and as the itching subsides, the wheal, or paler swelling, becomes less defined, and the more general swelling appears gradually to encroach on it and involve it. Then all subsides: but only for a time; for in about twenty-four hours a papule, or some form of secondary inflammation, appears, with renewed itching, at the seat of the

puncture, and this after one, two, or sometimes more days, gradually subsides.*

Now, the first pale and circumscribed swelling at any of these bites may serve to illustrate the immediate effects of a morbid poison on the tissues at and around the seat of inoculation. In the area of such a swelling the tissues are, by the direct contact or influence of the venom, altered in their nutritive relation to the blood. So, I believe, immediately after the insertion of syphilitic, vaccine, or other virus, there ensues a corresponding specific alteration of those parts of the surrounding tissues which afterwards become seats of the specific local disease.†

I will not venture to say that the secondary inflammation, which usually appears on the day after any of these bites, is to be ascribed in some measure to an influence exercised

* Some persons are so happily constituted, that they do not thus, or with any other discomfort, suffer the consequences of insect-bites; but I think the description I have given will be found generally true for cases in which the bitten part is left undisturbed. The fortunate exempt may illustrate the rarer exceptions from the usual influence of the severer morbid poisons.

† The direct influence of animal poisons on the tissues appears to be well-shown in the effects of the bites of the viper and rattlesnake. Sir B. C. Brodie particularly noticed this in a man bitten by a rattlesnake (*Lectures on Pathology and Surgery*, p. 345). The primary local, though widely extended, effect of the poison was a sloughing of the cellular membrane, which began "immediately after the injury was received." The poison "seemed to operate on the cellular membrane, neither in the direction of the nerves, nor in that of the absorbents, nor in that of the blood-vessels." His account has been recently confirmed in a more quickly fatal case. Many years ago, one of my brothers was stung by a Weever-fish (*Trachinus Draco*); and I remember that next day, though no severe inflammation had intervened, there was a little black slough at the puncture, as if the venom had completely killed a piece of the skin.

by the virus on the blood ; though, indeed, this will not seem impossible to those who are considerate of the effect of the minutest portion of vaccine virus, and of the intense constitutional disturbance excited by the other venoms. But, whatever be thought on this point, the occurrence of a new and different inflammation in the bitten part proves that it did not return to perfect health when its first affection subsided ; it proves that some altered material of the virus, or some changing trace of its effects upon the tissues, remained, altering their relation to the blood, and making them alone, of all the parts of the body, prone to specific disease. The bitten part thus, in its interval of apparent health, instructively illustrates the state of parts after inoculation with syphilitic or vaccine virus. In them, as in it, we must suppose that some virus, or some specific effect produced by it on the tissues, remains during all that period of latency, or incubation, as it is called, which intervenes between the inoculation and the appearance of the specific disease.

Whatever be the state thus indirectly induced in the inoculated or bitten part, let it be noted as one constantly changing. The tissues of the part, like the rest of the body, are engaged in the constant mutations of nutrition ; and the morbid material in the part is probably, like every organic matter, in constant process of transformation. Some of the local phenomena of specific diseases indicate these progressive changes in the part itself ; but they can scarcely be traced separately from those that are occurring in the morbid material absorbed into the blood.

The local and peculiar change produced by the direct effect of the morbid poison is essential to the complete manifestation of some specific diseases. In many others, as in typhus, variola, acute rheumatism, and gout, the morbid condition of the blood is sufficient to determine the local

disease in tissues previously healthy. But it is, perhaps, true for all, that the existence of some part whose nutrition is depressed, whether through simple or specific injury, is very favourable to the manifestation of the constitutional disease (see p. 442). Thus, I shall have to mention cases of cancer in which the constitutional condition, or diathesis, seems to have been latent till some local injury brought a certain part into a state apt for the cancerous growth,—the diathesis, as one may say, waited for the necessary local condition. In like manner, cases sometimes occur in which constitutional syphilis is justly presumed to exist, but in which it has no local manifestation till some part is appropriated for it by the effects of injury. I know a gentleman, who, for not less than five years after a syphilitic affection of the testicle, had no sign of syphilis, except that of generally feeble health; but he accidentally struck his nose severely, and at once a well-marked syphilitic disease of its bones ensued. In another case, syphilitic disease of the skull followed an injury of the head. In similar cases, ulcers like those of tertiary syphilis have appeared in healing operation-wounds. I lately saw a gentleman who had long suffered with diabetes, a condition with which, as is well known, boils often coincide. He, however, had none till he accidentally struck his leg, and the injury was quickly followed by a succession of more than twenty boils near the injured part. And, in like manner, as I have stated in a former Lecture (p. 444), even variola and measles may have their intensest local manifestations in injured parts.

I need not dwell on the importance of cases such as these, for caution against supposing that the diseases which seem to originate in local injury are only local processes. The most intense constitutional affections may appear almost irrespective of locality, able to manifest themselves in nearly every part; but the less intense may abide unobserved, so

long as all the tissues are being maintained without external hindrance or interference; they may be able to manifest themselves only in some part whose normal power of maintenance is disturbed by injury or other disease. It may, generally, also, be noticed that the more intense the constitutional affection, and the less the need for preparation of a locality for its manifestation, the less tenacious is it of its primary seat. Contrast, for example, in this respect, the fugacity of acute rheumatism or gout with the tenacity of chronic rheumatism in some locality of old disease or injury.*

II. Respecting, secondly, the changes which a morbid material, inoculated and absorbed, may undergo in the blood, these may be enumerated as the chief;—increase, transformation, combination, and separation or excretion. Here, again, one assumes for an example such a morbid material as may be inoculated; but it will be plain that most of what is said, in the following illustrations, might also be said of those that are otherwise introduced into the blood; and further, that the particulars of the life of these morbid materials are generally consistent with those of ordinary constituents of the blood.

(a) The *increase* of the morbid material in the blood is illustrated in syphilis, small-pox, vaccinia, glanders. In any of these, the inoculation of the minutest portion of the virus is followed by the formation of one or more suppurating structures, from which virus, similarly and equally potent, is produced in million-fold quantity. So, the matter of any

* Dr. Carpenter (l. c.) has clearly traced that epidemic and other zymotic influences bear, with peculiar force, on those in whose blood there is "an accumulation of disintegrating azotized compounds in a state of change." Is it not a similar degenerate condition which makes an injured part peculiarly amenable to the influence of specific morbid materials in the blood?

contagion working in one person may render his exhalation capable of similarly affecting a thousand others.

The increase is thus evident. The effect of the inoculated morbid poison may be compared with that of a ferment introduced into some azotized compound, in some of the materials of which it excites such changes as issue in the production of material like itself. What are the materials of the blood thus changed and converted to the likeness of the morbid poison, we cannot tell. The observations of Dr. Carpenter,* showing how peculiarly liable to all contagious and other zymotic influences they are whose blood is surcharged with decomposing azotized materials, may well lead us to believe that it is among these materials that many of the morbid poisons find the means of their increase. And, as Mr. Simon† argues, it seems nearly sure that certain of these poisons, in their increase, so convert some material of the blood, that they wholly exhaust it, and leave the blood for a long time, or for life, incapable of being again affected by the same morbid poison.

The increase of the morbid material, however effected, explains these characters of specific diseases:—the apparent disproportion between the specific cause and its effect (p. 481); the want of correspondence, in respect of quantity, between the local and the constitutional phenomena (p. 481); the seeming capacity of self-augmentation (p. 482).

(b) The *transformation* of a morbid material is indicated by the diversity of the successive manifestations of a single and continuous specific disease. Thus, in syphilis, the primary disease, if left to its unhindered course, is followed, with general regularity, by a series of secondary and tertiary diseases. The terms often used would imply that these dis-

* Loc. cit. p. 159.

† Lectures on Surgical Pathology, p. 262.

eases are due to a morbid poison which is, all along, one and the same. But, identity of causes should be manifested in identity of effects; the succession of morbid processes proves a succession of changes, either in the agent poison, or in the patient. They may be in the latter; but, regularly, they are in the former: for, on the whole, the succession of secondary and tertiary syphilitic diseases is uniform in even a great variety of patients. We may, therefore, believe that the regular syphilitic phenomena depend on the transformations of the morbid poison: their irregularities, on the peculiarities of the patient, whether natural or acquired from treatment.

The transformation here assumed is self-probable, seeing the analogy of successive transformations in all organic living materials. It is nearly proved by the different properties, in regard to communicability, of the syphilitic poison at different periods: in the primary disease communicable by inoculation, but not through the maternal blood to the fetus; in the secondary, having these relations reversed; in the tertiary, not at all communicable. In like manner, such facts as that the material found in the vaccine vesicle, on the eighth day, is better for fresh vaccinations than that taken earlier or later, prove successive transformations,—periods, we may say, of development, maturity, and degeneration, in the material of the virus.

Many similar phenomena of transformations in the morbid poisons may be cited; and if it may be accepted as a general occurrence, it will explain many of the phenomena of specific diseases. The period of incubation or latency of a disease (p. 484) may correspond with the transformation preceding the effective state of the morbid poison, with its periods of development. The prodromata, the precursive constitutional affections, and the successive stages of the disease, indicate the continuous transformations and varying influences of the

same ; just as every difference of organic construction indicates a difference in the yet unformed materials used in it. The increasing disturbance of the general health probably implies that the morbid poison increases while being transformed ; that it grows with its development. The periodicity of all these events (page 484) is a sign that the transformations of morbid poisons, like those of all other materials in the living body, are, in ordinary circumstances, accomplished in definite times. The sequelæ of specific diseases indicate yet further transformations, or, more probably, that the changes of the morbid poison have left the blood in a morbid state, through the exhaustion of some of its natural constituents, or through the presence of some complementary material.

(c) The *combination* of a morbid poison with one or more of the normal materials of the blood is indicated by the fact, that when the same specific disease, produced even by the inoculation of the same matter, affects many persons, it may present in each of them certain peculiar features. And these personal peculiarities, as they might be called, indicate modified qualities of the disease ; not merely such differences of quantity as might be explained by assuming that each person has, in his blood, a different quantity of such material as may be convertible into the morbid poison. Difference of quantity may explain (as Mr. Simon and Dr. Carpenter have shown) difference of intensity of specific disease, and difference of liability to epidemic influence ; but it does not explain the varied method of the same disease in different persons. For this, I believe, we must assume that the specific material of each disease may be, in some measure, modified by its combination with one or more of those normal materials of the blood which have, in each person, a peculiar or personal character (see p. 16, e. s.)

By such combination, we may best explain those cha-

acters of specific disease, which appear in its changes in transmission from one person to another (page 483) : such as the varieties of syphilitic sores, and the varieties of their consequences in different persons inoculated from the same source ; the change in the form of secondary syphilis or of cancer in transmission from parent to offspring ; the several peculiarities in the results of the same miasm when affecting ordinary persons, or puerperal women, or those who have survived injuries.

A remarkable instance, exemplifying, I think, as well the changes in the morbid poison itself, as its various effects on different persons, has been told me by my friend Mr. Huxley. One of the crew of H.M.S. Rattlesnake, after slightly wounding his hand with a beef-bone, had suppuration of the axillary lymphatic glands, with which typhoid symptoms and delirium were associated, and proved fatal. His illness began the day after the ship left Sydney, where all the crew had been remarkably healthy. A few days after his death, the sailor who washed his clothes had similar symptoms of disease in the axilla, and, for four or five months, he suffered with sloughings of portions of the cellular tissue of the axilla, arm, and trunk on the same side. Near the same time, a third sailor had diffuse inflammation and sloughing in the axilla ; and after this " the disease ran, in various forms, through the ship's company, between thirty and forty of whom were sometimes on the sick-list at once." Some had diffuse cellular inflammation ; some had inflammation of the lymphatic glands of the head, axilla, or lower extremities ; one had severe idiopathic erysipelas of the head and neck ; another had phlegmonous erysipelas of the hand and arm after an accidental wound ; others had low fever with or without enlargement of glands. " Finally, the disease took the form of mumps, which affected almost everybody on board." The epidemic lasted from May to

July. The ship was at sea the whole time, and, in the greater part of it, in the intense cold of a southern winter.

(d) The *separation* of the material of a specific disease may, probably, be accomplished in many different ways, and may be regarded as the final purpose (if we may venture to trace one) of the greater part of the morbid process. It is evident in the inoculable products of sores and pustules ; in the infectious exhalations of the skin, pulmonary, and other surfaces in the exanthematous and other fevers ; in the deposits in and near gouty joints. Analogy with these cases makes it, also, probable that the specific materials of several other diseases are separated from the blood accumulated at the seats of the local morbid process ; whence, if no organisms incorporating them be constructed, they may be re-absorbed after transformation. And it is nearly certain that the materials of most specific diseases may be excreted with the natural evacuations in the course of the disease, and this, either in their mature state, or after transformation, or in combination with the constituents of specific medicines.

The results of such separation or excretion are, also, various. Sometimes, it seems as if the whole of the morbid material were (after various transformations) removed, and the blood left healthy : as in small-pox, vaccinia, cured primary syphilis. Sometimes, part of the morbid material, transformed or combined, so as to be incapable of excretion, remains in the blood, and produces secondary phenomena or sequelæ of the disease. Sometimes, the production of the morbid material continues, notwithstanding the separation of what is already formed : as in the increase of the cancerous diathesis during the growth of cancers. Generally, in whatever manner the separation be accomplished, it is attended by such disturbance of the natural functions of parts, that serious disease is superadded to that which is

the more direct consequence of the presence of the morbid material in the blood. And lastly, a local disease which owes its origin, and for a time, its maintenance, to a specific morbid condition of the blood, may persist after that condition has ceased; the blood may regain its health by the separation of the morbid material, but the part diseased in the process of separation may so continue. Now, however, the disease may be wholly local, and curable by local treatment.

Thus may the theory of specific diseases be applied in explanation of their phenomena. I will only add that, in assuming all this of the changes occurring in morbid materials in the blood, we really assume little more than we believe of the organizable materials introduced, as nutriment, into the blood. If we could trace these, in their changes, first in the chyle and blood, and then in some complex tissue, then in the lymph and blood again, and again through the tissues of some excretory gland, we should trace a career of changes not less numerous, not less definite in method and in time, not less influential in the economy, than those which I have assumed for morbid materials in the blood. Only, the increase of the morbid material, and the apparent independence of its changes, are not imitated in the normal events of life.

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