Dr. Smith; but as similar ones are not of very unfrequent occurrence, we refer them to the work itself for the details of it.

To relieve this condition, it is open to us to cut away a portion of the affected nerve, or to perform a fresh amputation higher up in the limb. When the affected nerve can be clearly demonstrated, the first of these operations is indicated, but it is not to be forgotten that its success is uncertain; for not only may the tumour which is the cause of the distress be situated above the extremity of the nerve, but also there is at times a condition of chronic inflammation of the trunk and sheath of the nerve, which is itself a sufficient cause of the neuralgic distress.

There is yet another condition under which nerves are liable to enlargement, and that is when they are exposed to continued irritation, in which case they follow the ordinary law of hypertrophy. Naegele has described such a state as existing in the tibial nerve of a patient with elephantiasis; and Dr. Smith says, he has often noticed it in the ulnar and posterior tibial nerve, behind the olecranon and malleolus respectively.

Such are not, however, true examples of hypertrophy of nerves, they are swellings caused by the effusion and deposition of plastic matter in the neurilemma and its connecting cellular structure; facts that bear out the statement we have quoted from Rokitansky, that such tumours perform the office of bursæ.

We have thus fulfilled our promise, and placed our readers in a position to judge for themselves of the merits of Dr. Smith's work. We confess to have judged it by a high standard, perhaps the highest—to have adopted a lower one would, we conceive, have been to pay but a poor compliment to Dr. Smith; and if, according to this test, he has failed in accomplishing *all* that could be wished, he has, notwithstanding, produced a work that will long endure in honorable association with his name.

We repeat, that to all who have been concerned in its production—to author, draughtsman, publisher, and printer—the medical world owes a debt of gratitude, which will, we are sure, be as gracefully acknowledged, as it has been honorably earned.

ART. VIII.

1. *On Parthenogenesis, or the Successive Production of Procreating Individuals from a Single Ovum. A Discourse introductory to the Hunterian Lectures on Generation and Development, for the Year* 1849, *delivered at the Royal College of Surgeons of England.* By RICHARD OWEN, F.R.S., &c., Hunterian Professor and Conservator of the Museum.—*London,* 1849. 8vo, pp. 76. With one Plate.
2. *Lectures on the Processes of Repair and Reproduction after Injuries. Delivered at the Royal College of Surgeons of England, for the Year* 1849. By JAMES PAGET, Professor of Anatomy and Surgery to the College. (From the 'Medical Gazette.')

ALTHOUGH we have freely expressed our opinion, on a former occasion, as to the absence of all effort, on the part of the College of Surgeons, to sustain the dignity of the profession by the public advocacy of its rights, or to elevate its character by raising the tone of its examinations; and

although it has been too evident that, in the part it has taken in the Medical Reform question, it has been guided by a jealous regard for what it believed to be its rights and interests as a Corporation, rather than by a consideration for the general welfare of the body which it ought to represent; yet it is impossible to deny to it the credit of having most faithfully discharged one important trust which it undertook to fulfil, namely, the conservation of the Museum of John Hunter, and the propagation of the great principles which it was his glory to have enunciated. We shall not look back with even the shadow of blame over the long series of years during which these objects were very imperfectly effected. It was some time before the best methods were found out; it was not at first that the right men presented themselves. But the College can now boast of possessing in its Conservator and Assistant-Conservator, the two individuals most eminently qualified in this country for their respective offices; whilst of its Professors of Physiology and of Surgery, we believe that it may challenge the institutions of any age or country to produce the equals. Year by year are its magnificent collections now utilised by the men best able to develope and expound the great truths which they teach; year by year are some parts of the great design unfolded and displayed by those who have most profoundly and reverently studied it; and year by year are the opportunities thus presented to the metropolitan practitioner and to the advanced student, of learning, not merely the results of such studies, but the methods by which they have been pursued with such success. We cannot think of any kind of training more valuable than that, in which the learner is carried on, step by step, towards the perception of a great truth, in a style and with a manner that cannot but awaken his interest and fix his attention; and we have augured better of the rising generation of medical students, since we have seen with how much earnestness the benefits offered by the annual courses of Professors Owen and Paget have been embraced by no small proportion of those within whose reach they have lain.

Professor Owen, as is well known, has given to the world, from time to time, by separate publications, a portion of the valuable series of Lectures delivered in the theatre of the College. On the present occasion he offers us the introduction to his recent course on Generation and Development, which is designed as an exposition of a theory he has formed respecting the nature of that non-sexual mode of propagation, which has acquired so greatly increased an interest in later years, from the numerous additional examples of it which zoological research has brought to light, and from the attempts which have been made to generalize them.

Professor Paget's lectures for the present year form the continuation of the series of which we had the pleasure of noticing the commencement in our First Volume. The subjects of nutrition, hypertrophy, and atrophy, which he selected for his introduction, were appropriately followed last year by a course upon the life of the blood; but as this was not published, we had not the opportunity of bringing its principal topics before our readers, as we much desired to do. The present course forms a most natural continuation of the subjects of its predecessors; whilst it has happened, somewhat, as it would seem, designedly on Mr. Paget's part, that it has also formed a most apt sequel to Professor Owen's course, which it immediately followed. It being our purpose to take a somewhat critical

survey of the doctrines advanced in the lectures of both our Professors, we shall commence with the latter; since we think that our readers will be better prepared to consider Professor Owen's theory, when they have been put in possession of Mr. Paget's method of viewing those facts of an analogous character with which they are themselves practically familiar.

Mr. Paget commences his course by laying down the principle which forms the connecting link between his subject and his predecessor's; and this he does in the following elegant and felicitous manner.

"The mind, indeed, might gladly rest in the contemplation of such unhindered perfect works of Nature, as those of which he (Professor Owen) has discoursed; and it may at first seem an ungrateful task to turn from these, and consider the losses of perfection to which such works are liable, especially those losses which, being out of the ordinary course of Nature, abrupt and violent, we might expect would quite spoil the structure and the order of the living body. But, in truth, while studying the means by which living bodies, having suffered injury, regain their perfection, we may find continual manifestations of the same mysterious properties of the germ by which, through development, they first attained it. And in these manifestations we may discern the best evidence that, in developing the body to its perfection, the power of the germ is not lost, or quite exhausted, but rather is diffused through all the parts of the completed being; and that, so diffused, it works in them through all their life, determining, as with continuous design, every natural formative process, in accordance with the specific character of the individual. For I believe that we cannot form a just conception of the scope and nature of even the least of the processes of repair and reproduction after injury, or of the maintenance of the body in ordinary nutrition, or of its natural changes in the course of age, unless we admit that each organism, in its perfect state, retains, diffused through all its parts, some of the specific properties from which the power issued that actuated the impregnated germ in its development." (p. 1013.)

This doctrine, as he rightly states, is not new; being essentially nothing else than that of the "nisus formativus" of Blumenbach, and the "organic force" of Müller. But the general tone of modern physiology is considered by Mr. Paget as in some degree opposed to it; although we cannot but regard the opposition as more apparent than real. For although we may adopt the "cell-theory" to its fullest extent, and maintain that the vital actions of every component integer proceed from its own endowments as an independent centre of life; and although we may refer to chemical agencies some of the changes of composition which are concerned in the assimilating process; no one can overlook the fact, that in every organism these independent agencies are made to work together harmoniously for a common purpose, just like the separate performers in an orchestra, or the individual artisans in a factory. Mr. Paget, however, considers that both in the processes of common nutrition, and in the phenomena of repair and reproduction, "*a power* is in exercise, which is not admitted by the cell-theory, or by organic chemistry,—a power continuous with that manifested in the germ, and acting in all essential things like it." This power he thus defines:

"The characteristic property of an impregnated germ is, that when placed in favorable circumstances, all the materials of which it first consists, and all that it appropriates, are developed according to the same method as was observed in the development of its progenitors,—in other words, in conformity with what we may regard as a law of specific character. In all the wonders of development that my

colleague has detailed, none, I think, appeared more marvellous than the constancy, the seeming tenacity of purpose, with which the germ is thus developed to the likeness of its parents. However vast its power of multiplication and increase,—however various its metamorphoses,—however far in some of these changes it may deviate from the form in which its parents generated it,—however near in some it may approach the perfect characters of another species,—or, which is stranger still, however much alike all germs may be in their primal structure and earliest developments,—yet, through all these things, each germ moves, with unswerving progress, guided by the same Power as created its first parents, to the formation of a being in which the parental form and properties are reproduced.

"Now, the constancy of this result, and its little dependence on external circumstances, justify the expression that every impregnated germ has, in itself, and in the properties with which its Maker has endowed it, the power to develope itself into the perfection of an appropriate specific form. However mysterious the nature of such properties, we cannot deny their existence, or refuse to recognise a law (in the sense in which we generally use that term), in the regularity with which the power acts that issues from them, when the germ is placed in favorable conditions. And, therefore, if it appear that this power is peculiar in its modes of operation, we may specialize it, whenever acting, as the "power of the germ," or "germ-power," in consideration of its having its apparent origin and intensest action in the germ." (p. 1014.)

Now we cannot but perceive, in the foregoing extract and in other passages of a like nature in this most interesting lecture, somewhat of that tendency to attribute to intermediate powers or agencies what is nothing else than a manifestation of the *modus operandi* of the Supreme Power, which is, in our apprehension, the fatal error of many bygone systems of physics and physiology. We do not mean to say that Mr. Paget is himself chargeable with this error; indeed we think it impossible that a mind so sagacious as his can be led away by it; but we should have been glad if his phraseology had been such as clearly to explain that in attributing to this "germ-power" a certain series of phenomena, he means nothing else than that these phenomena take place according to a certain designed order and with a perfect mutual harmony, *as if* under the direction of some controlling agency. What that controlling agency can be, if not the Supreme Creator himself, we must confess ourselves at a loss to imagine. Nought but the lingering phraseology of bygone systems can prevent the logical mind, as it seems to us, from recognising the First Cause as in direct and immediate operation in the production of every natural phenomenon; and from doing away with the whole machinery of "secondary causes" as a philosophical fiction, ingenious and sometimes useful, but prejudicial, as leading to the belief that these "agents" are distinct *entities*, and that their "laws" have a power of action *per se*. This phraseology runs through our familiar language upon scientific subjects. Thus we say that a stone falls to the ground *because* of the law of gravitation; whereas the fact is, that the law of gravitation *is* a law—that is, a generalized expression of facts,—*because* all stones tend to fall to the earth, the earth to the sun, and all masses of matter towards each other. We talk, again, of a law *governing* the phenomena, as if it had power to coerce them; whereas the real state of the case is, that the phenomena take place *according to* a certain plan, of which that law is an expression, so far as the plan is known to us. Thus it is a law that heat causes the expansion of bodies, and cold their contraction; but this law cannot prevent the expansion of water as it cools from 39½° to 32°; and

it is evident that our law is imperfect, because we have not got at the whole truth of the case. So, again, we speak of having *explained* a phenomenon, when we refer it to a general law; the real fact being that, in so referring it, we merely place it on the same footing with other related phenomena, and are able from our knowledge of them to predict its occurrence under a certain set of conditions. Or, again, we say we have *explained* a phenomenon when we have been able to refer it to a certain "force," as that of gravity, electricity, chemical affinity, &c.; but this is no more of a real explanation than the other; for these "forces" are, like "laws," but generalized expressions of certain modes of agency which it is convenient thus to express, and particularly of such as can be rendered evident to our senses. Thus when we speak of the "force of gravity," we mean that tendency to the mutual approximation of all masses of matter, which manifests itself in their movement towards each other, or in the pressure they exert against ourselves if we attempt to antagonize it. And if we inquire into the source of that tendency, the cause of that pressure, it is obviously no answer to say, "it is the force of gravity," for this is merely changing one form of words for another; we can seek for the source and cause of these phenomena only in the will of their great Original Source, their great First Cause.

It is, doubtless, very convenient, in order to avoid continual reference to the Supreme and really Sole agent, to employ the terms "force," "law," "secondary cause," &c.; in fact, we can scarcely carry out a piece of philosophical reasoning or speculation without them; but still we think it incumbent upon any one who brings them prominently forward, and who seeks to establish the "laws" or to prove the existence of "forces," that he should clearly define the sense in which he employs them, in order to avoid the chance of leading his followers astray. Now in creating his "germ-force," and laying down the "law" of its action, without any such caution, Mr. Paget seems to us to lead his readers to suppose that this is some new controlling power, which is to overrule all the subordinate agencies at work in the organism, and to cause them to work together for a common end and on a common design. We cannot see how *any* power can have such a mediate agency between the Creator and any part of his works, unless it possess intelligence as its own attribute; and we are justified in this conclusion by the history of Dr. Prout's speculations on the subject. For, commencing with the idea of an "organic agent" as a being "endowed with little short of intelligence," he has at last been driven to regard it as actually "an intelligent being," residing in every organism, and directing all its operations. This seems to us to be the *reductio ad absurdum* of the whole doctrine of secondary causes as intermediate agencies; for we expect that few, save the worthy propounder of the hypothesis, will carry their love of philosophical fiction to such an extent, as to uphold the doctrine that not only animals but plants, not only the complex fabric of man, but the simple elementary cells of the aerial flags, are the habitations of these "intelligent agents."

We do not think it difficult to show that Mr. Paget's "germ-force" is nothing more or less than the comprehensive expression of all the individual forces, which are separately concerned in the evolution, maintenance, and reparation of a living being. Thus if we were so minded, we might say that the regular movements of the planets round the sun

take place, that their perturbations are controlled, and that the stability of the system is maintained, by a solar-system force; yet we know that the regular movements, the perturbations, the limitation of these apparent irregularities, and the continued stability of the whole, are secured, not by any such controlling power, but by the harmony of all the separate actions of each component, resulting from the perfection of the original design, and the uniformity with which it is carried into action. Reverting to our former simile of an orchestra, we might point out that it is only whilst the individual performers are imperfect in their parts, that a general control is requisite, and that control must be *intelligent;* when each performer knows his own part thoroughly, and has been trained to execute it in such a manner as to express the composer's meaning, the performance is independent of the "conductor," the most consummate harmony being evolved by the executive skill of the performers, who act out the mind of the composer. Is not this all that is requisite in an organized fabric, to build itself up, to sustain its perfection during its allotted period, and to repair the injuries to which it is subject? If the original design be perfect, and every component part be endowed with a capacity for executing its own share of it with similar perfection, what more can be needed for the production of the result? The wonder lies in the marvellous coadaptation of all the separate actions to the common end; a coadaptation that seems to us as remarkable in the history of the life of the simplest, as in that of the most complex organism. But the wonder should only lead us to look with increased admiration and awe at the wisdom of the Original Designer, which could thus provide for every contingency without any departure from the sublime uniformity of His action.

We have no objection whatever to the use of the term "germ-force" in such a sense as this; and heartily thank Mr. Paget for its introduction, since it affords us a convenient expression of the general fact, that the *mode of action* which we witness in the first development of the germ continues during the whole subsequent period of life; and serves to link together in the mind the various phenomena which manifest this continuity of the original plan.—We shall now follow him in his summary of these manifestations.

In the first place, as the "germ-force" tends always to the attainment of the perfection of the specific form, so it is strictly limited to the attainment and maintenance of that perfection, and to certain rules of time, space, and mode of progress. Wherever, then, in the full life of any creature, we see organic formation ensuing in conformity with these restricted laws, we may regard the germ-power as in action. This we shall find to be a characteristic of the ordinary reparative operations, which all tend to the more or less complete restoration of the lost perfection.

Secondly, this power is diffused through the several organs and systems of the body, and is manifested in their harmonious concurrence, with various time and measure, in the attainment of the design and destiny of the whole. Mr. Paget very justly points out that "it is only in few and trivial instances that we can regard the development of one part or system of an embryo as the consequence of the development of another; rather, the several systems and the parts of each are developed independently and commensurately." He considers, therefore, that the "germ-power" is

manifested in all those acts of adult life, in which a multiplicity of processes, effected by heterogeneous organs—all descended, however, from the original germ-cell,—is subordinated to an unity of purpose. This, too, is a striking characteristic of the reparative operations.

Thirdly, the germ-power manifests itself in its entire independence of any *model* existing in the structure itself. The ordinary assimilating processes act by fashioning the new material according to the model, and under the influence, of that in which it is inserted; but in embryonic development, there is no such precise imitation, for the very idea of "development" implies a change of condition; and "the only model after which each germ is developed, is that type according to which, from the first, and by the divine appointment, all the generations of its ancestors have been constructed." As examples of this mode of action in the adult body, Mr. Paget refers to that numerous class of operations in which the new parts are *not* developed from structures similar to themselves; such as the continued generation of epidermic and epithelial cells, of blood-corpuscles, of new teeth in fishes and reptiles, &c.; which were classed in his former course under the head of "nutritive repetition." All such phenomena, consisting in fact in the continued evolution of *new* parts, must be regarded as resulting from the continuance of the "germ-power," rather than from the ordinary assimilating power; and this, of course, holds good also in the production of new structures for the reparation of injuries.

The continuous action of the "germ-power" through life is further manifested in this—"that when, in an adult animal, a part is reproduced after injury or removal, it is made conformable, not to the condition which was proper to it when it was first formed, or in its infantile life, but to that which is proper according to the time of life in which it is reproduced—proper, because like that which the same part had, at the same time of life, in members of former generations." Thus, in the reproduction of the leg of the full-grown salamander after amputation, as described by Spallanzani, it is clear from the first that whilst the process itself is of a similar nature to that concerned in its first development, it is tending to produce, not the leg of a larva, but that of the adult animal. "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 now engages itself, with more energy, in the reconstruction of the whole."—To us it appears that, whilst it is convenient for the sake of the classification of the phenomena, thus to distinguish between the operations of the "germ-power" and the "assimilative force," we shall best keep in view their true relation, if we consider them both but as manifestations, under different conditions, of that original *nisus formativus*, which is in operation from the first commencement of the activity of the impregnated germ, to the final decay and disintegration of the structure into which it has been developed. The term *nisus*, moreover, seems less objectionable than "power," inasmuch as the former only expresses the *tendency* of a certain mode of action, whilst the latter conveys the idea that we have discovered the cause or source of the activity; and, as we have already attempted to show, the latter is far from being the

truth,—the only step we have gained, or are likely to gain, in this kind of inquiry, being the perception of the pre-existing unity in the plan of formation of each being, and in the methods adopted to carry it into effect.

Mr. Paget then proceeds to inquire into the principal conditions which affect the degree of this reparative power; and, first, of the place of the being in the animal series, respecting which he makes the following very discriminative remarks:

"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; 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 germ-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 issue from the mysterious properties of a germ is limited; that it is not ever communicated to an indefinite quantity of matter; and there are enough to justify the hypothesis, that the germ-power, thus limited, is in some measure consumed in the development of every new structure, and, in a less measure, in the growth and maintenance of those already formed. The instances to which I shall refer are explicable on this hypothesis, and are, therefore, evidences of its probability." (pp. 1018-19.)

He then adverts to the well-known facts which indicate, that the reparative power is greater in all parts of the young than of the older individuals of the same species, and that it is greatest of all in the embryonic state; and he shows that all these harmonize with the general statement, that the germ-power is more diminished by *growth* than by mere *maintenance*, but that it is most of all diminished by *development*; or, in other words, that the reparative processes are most completely effected in the earliest stages of development, but that as development advances they are less perfectly accomplished; that during the whole period of growth they are more active than after the full size has been attained, and that in adult age they are more energetic than in an advanced period of life. So, again, when we compare together the reparative powers in the adult state of different tribes of animals, we find that they may be generally said to vary inversely to the amount of dissimilarity between the adult and the embryonic states of each respectively.—In illustration of this view he refers to the extraordinary reproductive powers possessed by zoophytes and the lower articulata; and he quotes from the work of Sir J. G. Dalyell a very interesting experiment, which indicates that in these creatures the recovery from the effects of injury is gradual; a succession of heads being produced from the cloven stem of a tubularia, of which the first was imperfect, whilst the latter ones gradually improved until the normal conformation was attained.—So among the higher articulata, it appears from the observations of Mr. Newport that 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; thus the Myriapoda, whose highest development scarcely carries their external form beyond that of the larvæ of more perfect insects, the power of reproducing antennæ and legs is retained up to the time of their last moult; and among

hexapod insects, we find that the Phasmidæ, whose change of state is marked by little else than the development of wings, are those in which this power seems most enduring. On the whole, however, the class of Insects is the one of all the articulate series, in which there seems to be least reparative power: and it is remarkable that they should be inferior in this respect to the Arachnida, although the latter in many points of their conformation approach more nearly to the vertebrate type. Still more remarkable does it seem, that among Reptiles we should find so high a degree of reparative power persistent, as to suffice for the regeneration of a limb or an eye; when insects are so destitute of it. But we believe that Mr. Paget's principle completely holds good in these cases; for insects must be regarded as presenting the highest possible degree of development of the articulated type, which they only attain after a long series of metamorphic changes; whilst the arachnida reach their perfect state through a more direct development; and the salamander with its allies stands far lower in the vertebrated series than do the insects in the articulated, and a comparatively small amount of metamorphic change takes place in their passage from the embryonic to the perfect form.

The reparative powers of man and the higher vertebrata are limited, according to Mr. Paget, to the three following classes of parts:—1. Those which are formed entirely by "nutritive repetition," such as the blood and the epithelia:—2. 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. 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 more limited sense, i. e., in the place of what was lost, some lowly organized tissue is formed, which fills up the breach, and suffices for the maintenance of a less perfect life.

Deferring until the close of the present article, as its more appropriate place, the citation of the eloquent peroration with which this first lecture concludes, we shall now follow Mr. Paget through the principal details of the inquiry which he has thus introduced. In the second lecture he treats of the *materials* provided for the repair of injuries inflicted on the human body; understanding by the term injuries, visible breaches of continuity, such as wounds and fractures. There is every probability that recovery from the effects of disease takes place in conformity with the same general laws as recovery from injuries; but the whole details of the process have yet to be discovered. He commences by drawing attention to the very different conditions of a subcutaneous wound, and of one open to the air; a principle on which John Hunter insisted, and on which is founded the whole science of subcutaneous surgery. And he then announces, as the result of his own experimental inquiries, that "the materials produced for the repair of open wounds are not the same, or, at least, do not develope themselves in the same manner, as those for the repair of closed or subcutaneous ones."

That the blood extravasated in a wound may itself become organized—that is, may assume the characters of a tissue, and may coalesce with the

adjacent parts, and become vascular—was the doctrine, as every surgeon knows, of John Hunter; and although it fell for a while into disrepute, it has been clearly established by recent experiments and microscopic investigations (especially those of Dr. Zwicky), of which an admirable account was given by Mr. Paget, in his course last year. He now adds the following valuable observation, which he has himself had the opportunity of making since its delivery:

"The specimen 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 close 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, of such as Mr. Prescott Hewett has so fully described in his paper in the Medico-Chirurgical Transactions. 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 a sketch, from which the diagram was copied. The arrangement of blood-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 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; neither are they seen in any stage of the organization of such lymph as is commonly effused in inflammation; but they exactly resemble such as may be found in certain examples of rudimental 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.'" (Lecture ii, p. 1066.)

It is certain, however, that extravasated blood has ordinarily no share at all in the reparation of injuries; the smallest portion of blood being effused in the cases in which the largest quantity of reparative material is produced in the shortest time, and in which the healing process is most perfectly accomplished. Thus, in cases of subcutaneous division of tendons and fracture of bones, it is rare to find clots of blood lying between the divided parts. When blood is effused into open wounds, it seems to have less tendency to become organized than when poured into a closed cavity; and it is liable to act as a foreign substance, especially if effused in large quantity, and to excite inflammation, so that the tumefaction of the parts, or their incipient suppuration, pushes it out of the wound. In more favorable circumstances, the blood is absorbed; but Mr. Paget states, as the result of his observations, that this absorption is much less rapid than is commonly supposed, and that it is not effected in order to make way for the effusion of other reparative material, but is actually a consequence of that effusion, being inclosed within it, and absorbed by the vessels which are developed in its substance as its organization proceeds. Still he believes that blood effused into wounds *may* be organized and form part of the reparative material; but as its progress towards organization is

much slower than that of coagulable lymph, the healing of the wound is probably retarded by its presence.

The fibrinous plasma, or coagulable lymph, which is effused into wounds as their proper reparative material, does not seem to differ in any essential characters from that which is poured out on the surface of serous membranes. Its distinctive vital endowment is its tendency to spontaneous development into a fibrous tissue; but this, according to Mr. Paget, may take place in two modes. For the plastic material which is produced for the repair of open wounds, generally developes itself, in the first instance, into cells, from which the fibrous tissue is formed by a subsequent metamorphosis; whilst that which is poured out for the healing of subcutaneous wounds, as generally developes itself into fibrous tissue by the fibrillation of the blastema, in which nuclei are present, but no cells. "Both these," remarks Mr. Paget, "are repetitions of natural modes of development of the same forms of tissue. In the embryo and fœtus you may trace very well the development of subcutaneous cellular tissue through nucleated cells, and that of tendons and other *formed* fibro-cellular or fibrous tissues through nucleated blastema." It need not appear an objection to this statement, that there should be two modes of development for the same tissue; for this is seen in the case of the blood-corpuscles, as explained in Mr. Paget's former course; and it is now well known to be the case also in the production of bone.

The development of the fibro-cellular or connective substance through the medium of cells, may be observed in the material of granulations, or in a wound healing by primary adhesion, as well as in inflammatory adhesions. The cells, at first, bear a close resemblance to the colourless corpuscles of the blood; but they gradually elongate, and attenuate themselves into the filamentous form. It was stated by Schwann that such cells metamorphose themselves into *fasciculi* of fibres, but Mr. Paget has not seen a single cell form more than a single filament; the long filaments, indeed, being formed of two or more cells, attached end to end. The nuclei seem to take the initiative in this metamorphosis, becoming oval even before the cell does; in other cases, however, the cells seem to take on the reproductive instead of the metamorphic action, in which, also, nuclei are the prime agents,—large compound cells being frequently met with in granulations, containing eight, ten, or more nuclei, pretty evidently derived from the subdivision of the original nucleus, and destined to be developed into new cells. Mr. Paget has not been able to trace the further development of the nuclei of the filamentous cells into fibres of elastic tissue (as described by Henle) in the tissue of granulating wounds or inflammatory exudations; the nuclei appearing rather to waste and be absorbed.

On the other hand, the development of fibrous tissue through nucleated blastema is observed in the material poured out for the reparation of subcutaneous wounds. The following is Mr. Paget's account of the process, as traced by him in the reunion of divided tendons.

"When the first effusion of the products of the inflammation, excited by the violence of the wound, is completed, then 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 fibrine; but as it acquires firmness and distinctness, the nuclei appear in it; they seem to form out of collecting clusters of granules, and presently appear as oval bodies, with dark hard outlines, soon becoming elongated, with clear contents, without nuclei, 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 acquire dark edges and shrivel up a little. The nuclei undergo 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.

"The blastema may become at length perfect fibro-cellular or fibrous tissue,—tissue not to be distinguished from that found in normal conditions. The final disposal of the nuclei is doubtless sometimes, as Henle describes it, that they are developed into the nucleus-fibres, and constitute some of the various forms in which elastic yellow tissue is found mingled with the proper white filaments. But, 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 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." (Lecture ii, p. 1071.)

Now this description as closely corresponds with Henle's account of the mode in which the fibrous tissues are at first formed, as did the preceding account of their production by the metamorphosis of cells with that of Schwann; and Mr. Paget's observations thus go to prove that both these admirable anatomists are right in what they severally affirm, though both are wrong in conceiving the method witnessed by them to be the only one. For whilst the development of fibres in a nucleated blastema appears to be the regular mode of formation and of reparation in the case of tendons and ligaments, that by the metamorphosis of cells appears to be equally characteristic of the formation and reparation of the subcutaneous areolar or fibro-cellular tissue.

The formation of the cell-tissue appears to take place wherever inflammatory action participates in the reparative processes; "for of such cells, in various stages of development, are formed not only long suppurating granulations, but also the walls of abscesses, inflammatory infiltrations, producing succulence, induration, and thickenings of soft parts; and in the lymph produced in inflammation of serous membranes, which organizes itself into false membranes." In the early stage of the reparation of most wounds in warm-blooded animals, some indications of this process may be traced. But it speedily gives place, in subcutaneous wounds, to the other method, which we find to prevail in morbid processes in which there is no sign of inflammation; as, for example, in the growth of warts and condylomata, in the simple fibro-cellular tumours of the subcutaneous tissue, in nasal polypi, and in organizing clots of blood. We therefore seem justified in concluding, generally, "that inflammation ensues in the healing by adhesion and granulations, but does not exist in the healing of subcutaneous wounds."

Mr. Paget next proceeds to speak of the different modes of healing of

wounds; and in the first place of such as are externally open. He first describes that which was designated by Hunter (who erred in imagining, however, that a stratum of blood is the connecting medium) as "union by the first intention;" but as that term is now generally applied to another process, he adopts from Dr. Macartney the term "immediate union" to designate that which is effected by the simple adhesion of the wounded surfaces, without any connecting medium of blood or lymph. It seems to have been supposed by Dr. Macartney, however, that such union can only take place in the case of comparatively small and simple incised wounds, such as cuts of the finger or hand; but Mr. Paget has no doubt that even very large wounds, such as those made in the extirpation of mammary tumours, are thus healed under favorable circumstances. In support of this statement he details an extremely interesting case in which he was afforded the opportunity, by the death of the patient from erysipelas, of examining the condition of a wound of this kind, the greater part of which had healed rapidly; of which he says that "the state of parts cannot be better described, than by saying that scarcely the least indication remains, either of the place where the flap of skin was laid on the fascia, or of the means by which these parts 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 tissue beneath it;" and no lymph- or exudation-globules could be discovered by the most careful microscopic examination. This view of the case he has confirmed by experiments upon animals. He justly designates this "immediate union" as "the best imaginable process of healing;" and points out its two essential conditions, as being the exactness of the coaptation of the wounded parts, and the absence of all inflammatory action. The following practical hints founded on these views are well deserving of the surgeon's consideration.

"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 venture to express my belief 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,—and, I think, the majority,—they are avoided, through fear of exciting inflammation by overheating 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 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 never 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 ensuring 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 and rest. 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. (Lecture iii, p. 29.)

Not many years since, it was imagined that Hunter's "union by the first intention," and "union by adhesion," or by "adhesive inflammation," were one and the same thing, the only difference being in the degree of the inflammation concerned. We have seen, however, that although Hunter was wrong in the opinion that *blood* is the connecting medium in such cases (since blood cannot undergo organization so rapidly), yet an immediate union without inflammation may take place; and the process is very distinct, therefore, from those in which inflammation essentially participates. The first of the latter is appropriately distinguished by Mr. Paget as "primary adhesion," in contradistinction to that by granulations, which is called "secondary adhesion." The former is seen, as every surgeon knows, in cases of incised wounds the edges of which are not brought into perfect coaptation, or in which some inflammatory action is present which gives rise to effusion of lymph. In either case, the connexion is finally re-established by the organization of the lymph, into which vessels pass from both surfaces; but the intervention of this bond is manifested by the persistence of the cicatrix, which is indicated by the peculiar condition of the newly-formed skin. A very good example of this process, as it takes place under favorable circumstances, is presented after operations for harelip; the wound left by which, however, may partly heal by "immediate union." The steps by which the plastic effusion becomes converted into tissue are essentially the same as in the "secondary adhesion," which occurs in cases where the wounded surfaces are not united by either of the foregoing means, but are, in the ordinary phrase, "left to granulate." The first stage in the healing process of open wounds is the formation of a "glazing" on the exposed surface, which closely resembles the buffy coat of the blood, being composed of coagulated fibrine and colourless corpuscles. Mr. Paget attributes the presence of the latter simply to their peculiar adhesiveness, which makes them less readily flow from the blood-vessels when the bleeding is about to stop; so that afterwards, 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 roll. The adhesiveness of which he speaks appears to be merely physical, and dependent upon the nature of their surface; we scarcely think that he allows enough weight to the attraction which they seem to have for any of the solid tissues which are in state of exalted formative activity, as manifested by their stagnation and accumulation in the vessels of such parts. The increase of this "glazing" is the prelude of the formation of granulations; but whilst it is going on, there is, in and about the wound, an appearance of complete inaction, a sort of calm, in which scarcely anything appears except a slight oozing of serous

fluid from the wound, and which continues 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.

"These periods of repose after severe injury are of equal interest in physiology and in surgery; but in the former it is only the interest of mystery. Observations on injuries of the frog's web make it probable that the blood is stagnant 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 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 more often at or near the end of this period than at any other time. Moreover, in general, 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 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. 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." (Lecture iii, pp. 31-2.)

The cessation of this period of calm, and the active commencement of the reparative operations, are marked by the restoration of the flow of blood in the vessels of the wounded part; but the current is not altogether normal, being slower but fuller than natural, so that on the whole more blood than usual passes through the capillary plexus. It is possible, too, that new vessels may be generated during this time. Mr. Paget regards this state of the circulation as an indication of the existence of an inflammatory condition; but we can scarcely so consider it, since, in our apprehension, genuine inflammation does not exist without inflammatory effusions. He seems to think, too, that the ordinary law of the capillary circulation, which we are glad to find that he fully recognises,—namely, that "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 formative actions of the part,"—is suspended in this abnormal state; the increased supply here preceding the increased production of the material. It does not seem to us difficult, however, to reconcile the two facts; for it appears that, in the first instance, the "shock" of the injury has so depressed the formative powers of the parts which have sustained it, that the circulation in them is altogether stagnated; whilst, on their recovery from this, and the recommencement of their formative activity, the still-depressed vitality of the walls of the vessels occasions them to yield to the pressure from within, and thus allows them, by their distension, to give passage to a larger current. However this may be, the increased afflux of blood here precedes the formation of plastic material

in increased proportion; and it is from the effusion of this material, that the granulating process properly commences. This process may take place in the healing of subcutaneous wounds, the granulations being then composed of "nucleated blastema," and being free from suppuration. But in by far the greater proportion of cases, granulations are only formed in exposed injuries; they consist of cells, which may develope themselves into fibro-cellular tissue; and they have a suppurating surface. The formation of this tissue and of the investing skin takes place in a manner essentially the same as in the embryonic state; and it is interesting to remark, that we find the character of the new cuticle varying, as in the fœtus, with the part on which it is formed, being more opaque and thicker on the soles of the feet and the palms of the hands than elsewhere,—another instance, as Mr. Paget justly remarks, of the identity of the powers that are put in operation in the acts of first construction and of repair. But the latter process is more liable to defect or error than the former; so that, by arrest of development, by degeneration, or by complete decay, the granulation-cells are prevented from developing themselves into the new tissue which it is their purpose to generate, and the wound does not heal.

Mr. Paget's observations lead him unhesitatingly to adopt the conclusion of Valentin, Gerber, and others, that *pus-cells* are nothing else than ill-conditioned granulation-cells; but he points out that this lower condition may be acquired in two modes,—either by degeneration from a previously higher development, or by originally imperfect development. And, in like manner, he regards the *liquor puris* as the degenerate form of the solid blastema, being composed of albuminous matter incapable of organization. This is the doctrine which has always appeared most probable to ourselves; the microscopic observations which we long since made having led us to the belief, notwithstanding the positive statements of many practised observers, that no distinct line of demarcation can be drawn between the "exudation-cell" of inflammatory lymph, the "granulation-cell," and the "pus-cell," either of the two former showing every gradation of form and condition to the latter. We are, therefore, very glad to find our views confirmed by the far more comprehensive and elaborate researches of Mr. Paget; and are disposed to consider the question as now settled in the conclusion, "that the true relation which the cell in granulations or in inflammatory lymph holds to the pus-cell, is that of a well-organized structure to the same structure either ill-developed or degenerate after having, up to a certain point, been duly formed." The following extract will show the felicity with which Mr. Paget brings facts with which every practical man is familiar, to the support and illustration of his doctrines:

"An observation, which any one may easily make, seems to indicate that the liquor puris may be the product of the degeneration and liquefaction of the solid blastema, as the pus-cells appear to be of the granulation- or exudation-cells imbedded in it. If the formation of abscesses 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 exudation-cells degenerating into pus-cells, its blastema into liquor puris.

"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 the inflammatory product, first formed as a soft solid, degenerates and becomes fluid." (Lecture iv, p. 77.)

Mr. Paget adds the suspicion that other rudimental forms of tissue may, in degeneration, sometimes assume the characters of pus-cells. This, he thinks, may be the case, for example, in regard to mucus-cells; since the pus so readily secreted from inflamed mucous membranes exhibits forms of transition between the two. And the line of distinction between pus-cells and the colourless corpuscles of the blood is equally indefinite; so as to suggest whether the purulent diathesis may not have its essential anatomical character in the degeneration of these corpuscles, possibly induced or favoured by the introduction of pus already formed into the blood.

Whilst the conversion of the granulation-cells into fibrous tissue is thus going on in the part most removed from the exterior, and their degeneration into pus-cells is taking place on the surface, the substance of the granulations becomes vascular, and nerves also may possibly be developed in it. We have here a plain indication, however, that organization is independent of what has been frequently but erroneously called "vascular action;" for not merely are the cells developed in the blastema, but their metamorphoses are making considerable progress, *before* the granulations are penetrated by blood-vessels; and the purpose of these is obviously nothing else than to supply the materials for further development, the afflux of blood being obviously proportional to the activity of the changes taking place in the part, and lessening with their diminution. The mode in which the formation of vessels in a new part takes place, is a question which has been hotly discussed by different observers; and here, as elsewhere, Mr. Paget shows that their apparently opposite views are not really inconsistent, since the process takes place on either of three different plans, according to the circumstances of the case. His account of these plans is so valuable for its clearness and comprehensiveness, that we shall quote it nearly in full:

"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. Thus, in the larvæ of Batrachia, as in the common tadpole, before even the walls of a heart are formed, one sees a crowd of embryo blood-corpuscles collected where the heart is to be; and, in the substance of the out-growing external branchiæ, are looping lines of blood-corpuscles, around which as yet no walls can be discerned. It is so, also, with the blood and vessels of the warm-blooded vertebrata; the corpuscles are rapidly developed from some of the cells of the germinal area, and are laid out in the plan of the heart, and the terminal sinus, and their communicating channels. But at first it is only as a plan; the blood does not move, and is not walled in. Then, as the heart and vessels are formed around the blood, its circulation in these simple channels is established. In this case, the

vessels appear to be formed of the plasma of fluid material which lies between the cells, and gradually assumes the condition of a membrane, and is then developed into the more complex structures of the blood-vessels.

"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 be added in adaptation to the enlargement and increasing complexity of the embryo, two methods are observed; of which the one appears chiefly appropriate to the interstitial formation of new vessels; the other, for the construction of those of superadded or outgrowing parts.

"For the former, one finds, in the interspaces of vessels already existing, primary cells, which enlarge and elongate, and send out branches in two or more directions, —branches sometimes so exceedingly slender, that one might take them for mere threads of embryonic fibro-cellular tissue. But they 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 stellate 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, and through these the blood, entering by the openings of communication with the older vessels, makes its way. Thus the wide spaces of the network formed in the primordial circulation are subdivided into smaller meshes, and each part receives a more abundant supply of blood. Such a development (as shown in the diagrams) may be seen in the soft gelatinous matter within the amnion of embryo-sheep, and in the tissue of the tail of the tadpole; though in this last the development is often abortive.

"But, for parts that are formed by super-addition or out-growth, another mode of development of blood-vessels is observed; and this, I believe, is the only mode in which new blood-vessels are ever formed for granulations, or for superficial deposits of lymph, adhesions, and the like. 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 I have described, and no appearances are found which would justify a suspicion that either of the other methods of development has 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. The vessel will first present a slight dilatation in one, and coincidently, or shortly after, in another point, 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 such outgrowths formed. The plan on which they are arranged is made more complex by the similar out-growths of branches from adjacent arches, and their mutual anastomoses; but, to all appearance, the whole process is one of out-growth 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 their diameter—should 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 the life.

Observe, that no force so simple as even that of growth or mere 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 a power determining the concurrent development of the two out-growing vessels, in conformity with the same law as that according to which the same power actuates the germ. 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 blood-corpuscles that issue from the ruptured pouch or diverticulum 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 insects the blood habitually flows, in a considerable and important part of its course, through sinuses, spaces, or channels without proper walls, such as are here supposed to exist only for a time. In such channels, too, it seems very probable that the blood moves in part of its course through some of the softer medullary and other morbid growths; at least, in these I have often found it impossible, with the microscope, to detect even the rudiments of such vessels as could carry their great supplies of blood." (Lecture iv, pp. 70-2.)

The structure and arrangement of the vessels of granulations,—whether those of wounds, ulcers, or the walls of abscesses,—correspond with the plan of development by "out-growth." In the earliest period of their appearance they present no indication of being formed by the fusion or any transformation of the granulation-cells; but consist of thin membrane, in which, if it be not quite simple, nuclei are imbedded, which gradually come to present the same appearances as those exhibited by original vessels of the same size. And the plan of their disposition is at first what might be expected on this idea of their mode of formation; the arched arrangement being obvious enough near the surface of the granulations, and being discernible in the deeper portions. With regard to nerves, Mr. Paget says that he has never been able to see any, either in granulations or cicatrices; and he seems almost inclined to attribute the sensibility which granulations appear to possess, to that of the excited tissues from which they spring: of their presence in cicatrices, however, we should think that no reasonable doubt can exist. From the investigations of Professor Schrœder Van der

Kolk, it appears that lymphatics do not exist either in granulations or cicatrices; although he has succeeded in demonstrating them in false membranes.

When two opposite surfaces of granulations, well developed, but not yet covered with cuticle, are brought into apposition, they have a tendency to unite, like the two original surfaces of an incised wound; this union, which was noticed by John Hunter, is appropriately termed by Mr. Paget "secondary adhesion." He gives the following examples of it, which serve alike to indicate its nature, and to point out the practical applications which may be made of this knowledge:

"There are several circumstances in which the healing by secondary adhesion should be attempted,—such, for example, as I witnessed in a case which was lately in St. Bartholomew's. After an ordinary circular amputation of the thigh, no immediate union and no primary adhesion had taken 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 with manifest advantage.

"Again: Mr. Hunter operated for harelip, 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 very edges of the wounds sloughed and retracted, and the case seemed nearly hopeless; but he kept 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 in practice, certain conditions are essential to success; especially that—first, the granulations should be healthy, not inflamed or profusely secreting, or degenerated, as those in sinuses commonly are; 2dly, that the contact between them should be gentle but maintained; and perhaps they should be as much as possible of equal development and alike." (Lecture iv, p. 74.)

The healing of wounds by "scabbing" is next brought under consideration by Mr. Paget. This is, as John Hunter observes, the most natural mode, for it requires no art; and it is the method according to which we see nearly all open wounds healed in animals, even the warm-blooded. The formation of a scab, in fact, reduces the wound more nearly to the condition of a subcutaneous one; so that the reparative growth and formation of new tissue take place, under favorable circumstances, without any suppuration, and with scarcely any irritation; the subsequent cicatrix, too, being much more like the natural parts than are any scars formed in wounds that remain exposed to the air. It is obvious, then, that it would be very desirable to heal all wounds by scabbing, which cannot be brought to close by immediate union or primary adhesion; if it were not that in the human subject the process is far less certain than it is among animals, owing to the liability to inflammation in the wounded part, and

the consequent effusion of fluid, which produces pain, compresses the wounded surface, or forces off the scab, with great discomfort to the patient, and retardation of the healing. The many instances of disappointment from this cause, seem to have led to the general neglect of this process in the treatment of wounds; but we quite agree with Mr. Paget in the belief that the observance of perfect rest and of the other means for warding off inflammation might yet make it an available auxiliary in the treatment of wounds, especially of large superficial ones (collodion answering all the purpose of a scab in the treatment of smaller ones); and we are strongly inclined to believe that the cause of failure is chiefly to be looked for in the *unnatural* condition in which by far the larger proportion of our population habitually live,—the experience of less civilized nations having abundantly shown that continual exposure to fresh air, the moderate use of wholesome food, and complete abstinence from stimulants, will place the human subject on a most desirable level with the lower animals, in regard to the healing of wounds. And the experience of travellers and sojourners among them, who have conformed to these habits, is equally favorable; showing that the variation is not due to difference of race, but to constitutional state induced by mode of life. Seeing, as we continually do, the effects of foul air, of habitual excess in diet, and of the constant abuse of stimulants, in impairing that form of the restorative process which must be regarded as the least favorable, namely, the closure of a wound by suppurating granulations, it cannot be thought improbable that to induce the more favorable method, the most perfect freedom from all such pernicious agencies should be maintained. Mr. Paget does not admit the "modelling process" of Dr. Macartney to be anything else than healing by granulations under the most favorable circumstances; and in this we have little doubt that he is right. But the surgeon should surely endeavour to ascertain what these conditions are, and to make them to apply as far as possible to every case in which he is called upon to superintend the reparative processes, so as to bring about the most favorable issue that the nature of the injury and the constitution of the patient admit of. Nothing can so much conduce to the acquirement of this knowledge, as the scientific study of the various modes of reparation; and we trust that Mr. Paget will find opportunities of carrying into extensive practical application the conclusions to which his valuable investigations on this subject have led him, and will at some future time communicate to the public the results of his inquiries.

Mr. Paget's Fifth Lecture is devoted to the history of the reparation of fractured bones. Upon a subject which has already been so fully investigated by men of distinguished ability, it might be thought that little remained for him to say; but even here we meet with important results from his original researches, which show that even the most hackneyed topics will yield an abundance of novelty in the hands of a really original investigator who interrogates nature in a right spirit. The points which he has specially chosen for elucidation in this lecture are, first, the differences between the process of the reparation of fractured bones in man and that which has been so fully investigated in the lower animals; and, second, the nature of the reparative material previous to its ossification. On the first of these points he says:—

"I must express my conviction that the description drawn by Dupuytren and others, from examinations of fractures in dogs, rabbits, birds, and other animals, cannot be applied without great deductions to the case of fractures in the human subject. True as the pictures are of the cases of the animals examined, they are exaggerations of the process in our own case. With a few exceptions, all that is written in these accounts of external and internal, provisional and definitive, callus, of the formations of cartilage and bone within the medullary tube and beneath the periosteum, can be traced only, as it were, in rudiment in the fractures of the human bones. . . . .

"For fractures in the human subject, the evidence that union is accomplished by the reparative material being placed between, not within and around, the fragments —i. e., as an intermediate, not an ensheathing callus—this evidence may be obtained by the examination of such fractures even long after they are completely healed. In as many as you like to examine you will find the new bone formed exclusively between the fragments. Whether they were in apposition, or nearly so, or wide apart, still there is no appearance of new bone being formed on the outer side of any fragment—I mean on that side which is turned away from the other fragments. And this is the case even in those instances in which there is so much displacement of the fragments, and so much distortion, that we can hardly suppose the repair to have proceeded very quietly. Neither in any of these do you find new bone within the medullary tube. It may be objected by some to these specimens, that the fragments were once ensheathed and blocked up with callus, and that it has been since absorbed. But this is not probable, seeing that in many cases there remain, on the outer surfaces of the fragments, certain marks of their original form and slight irregularities. In one of the specimens which I present, we have traces of the healing of a long fissure, which appears now as a sunken groove, making it nearly certain that no new bone was formed over it. In another, is a detached piece of the wall of a femur turned quite round, so that its periosteal surface lies on the periosteal surface of the principal fragment; yet on the outer surface of this piece (which was the inner surface of its wall) the thin plates forming the boundary of the medullary tube are still unchanged.

"But if any deem these and the like characters insufficient to prove the absence of ensheathing callus, and of callus extending into the medullary tube, yet recent specimens are not open to such doubts. I add, therefore, that (with the exceptions presently to be mentioned) in all the specimens of fracture that I have been able to examine, in the human subject, within six months of the time of the injury, there has been the same absence of provisional or ensheathing callus." (Lecture v, pp. 116-17.)

This difference appears to depend upon the quietude in which fractures of human bones are usually maintained, even independently of surgical care; and on the naturally greater tendency to the production of new bone, which animals always manifest. The influence of the first of these conditions is well marked by the fact, that the exceptional cases just referred to, in which a provisional callus is generally or naturally formed for the repair of fractures, are the ribs, whose immobility cannot be secured; whilst it is sometimes noticed also in fractures of the clavicle, in which there has been a want of repose.

As an introduction to his account of the reparative processes of bone, Mr. Paget gives a brief account of the researches which have led to the conclusion, that a large part of the later growth of bone consists in the calcification of a fibrous tissue, and is not dependent on the pre-existence of cartilage. Dr. Sharpey's observations on this subject have been confirmed and extended by that most accurate observer Kölliker; who has shown that in the increase of all the bones of the skeleton by superficial deposit,

that deposit takes place in the substance of their fibrous investment. The ossicula of the ear are the only bones which attain their full size in the cartilaginous state; and the only participation which cartilage has in the development of any bones subsequently to their first ossification, is in the cases where a layer of cartilage intervenes between the principal mass of the bone and its epiphyses, this layer being in a state of continual growth, whilst the portion of it in contact with the bone already formed progressively undergoes ossification. Thus a long bone increases in *length* by means of the cartilages interposed between the shaft and the epiphyses; but it increases in *diameter* by the ossification of the fibrous tissue commonly regarded as the inner layer of the periosteum.

In the reparation of fractures, according to Mr. Paget, we may find several varieties of the ossifying process, which show us how Nature (so to speak) can take advantage for this purpose of the ordinary operations of reparation. First, it may be accomplished through perfect fibrous tissue; that is to say, the effused plasma may proceed to that grade of organization before ossification commences in it, which is believed by Mr. Paget to be ordinarily the case in the formation of new bone after fractures of the skull; or the new bone may be formed in fibrous tissue previously existing near the seat of the fracture, as in the periosteum or interosseous membranes. —Secondly, the new bone may be formed by ossification of the fibrous tissue in a rudimental state; and this may be that either of nucleated cells or nucleated blastema. The ossifying process takes place at the expense of the first of these materials when it occurs in granulations or inflammatory effusions; as is frequently seen in compound fractures, but best of all in the formation of that mushroom-shaped mass of granulations which is protruded through the medullary canal of a bone sawn across in an amputation. The ordinary mode of reparation, however, is believed by Mr. Paget to be still simpler; namely, the ossification of a nucleated blastema or rudimental form of fibrous tissue; a finely and very closely granular osseous deposit taking place in it, and gradually accumulating so as to form the delicate yet dense lamellæ of fine cancellous tissue. The nuclei of the blastema appear to become inclosed in the newly-forming bone, and to constitute, in fact, the bone-corpuscles, occupying the places which are afterwards to become the lacunæ. This we apprehend to be the mode in which all but the first imperfect network of bone is formed in even the intra-cartilaginous ossification; for after the disappearance of the cartilage-cells and the coalescence of some of the first formed areolæ, we find the spaces which are afterwards to become the Haversian canals and cancelli filled up with a "nucleated blastema," which evidently becomes converted in some mode or other into the lamellæ of osseous substance, by which the inclosing walls are progressively thickened.—But thirdly, that the reparation may take place through the medium of cellular cartilage, has been established by the observations of Miescher and others upon dogs, pigeons, &c; but Mr. Paget has not met with any examples of it in the human subject, though he considers that it might not improbably occur in favorable instances of simple fractures in children. In youths and adults he has found only varieties of fibrous cartilage, presenting various intermediate gradations of structure, from the simply fibrous to the perfect cartilaginous. In advanced life there seems to be a tendency to the production of fibrous rather than of cartilaginous tissue; and wherever the ossifying

process is imperfectly performed, we find that it is by ligament, not cartilage, that the bones are held together.

"Through any of these structures, and apparently by the same method through all, 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 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.

"The new bone, through whatever mode it be formed, appears to acquire quickly its proper microscopic characters. Its corpuscles, 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 corpuscles. The laminated canals for blood-vessels, I think, are later formed. At first, all the new bone forms a minutely cancellous structure, much like that of the fœtal bones in their first construction; but this gradually assimilates itself to the structure of the bones that it repairs, while its outer portions assume a compact laminated structure, and its inner or central portions acquire wider cancellous spaces, and a more perfect medulla. 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. Only, specimens and drawings, one and all, show the most striking evidences of design in the adaptation of the reparative process to the particular exigencies of each case; so that it might be said, with complete truth, of every instance, that whatever is necessary,—whatever may best, under the circumstances, repair the damage,—that is done." (Lecture v, p. 121.)

The last Lecture is somewhat fragmentary, treating of the repair of injuries of cartilage, tendons, muscles, and nerves.—On the first point, Mr. Paget has no new facts to offer; the absence of any power of reproduction of true cartilage after injuries of this tissue, which are repaired either by fibrous structure or by bony deposit, being already well known. He makes the ingenious remark, however, that notwithstanding the non-vascularity of cartilage and the vascularity of bone, the replacement of the former by the latter must be considered as a process of degeneration rather than of development. This is indicated by the fact that in cartilage true interstitial growth can take place; whilst in bone no change can be effected but by superficial deposition and removal. So, again, the granular deposition of earthy matter in an animal tissue is everywhere else considered as a process of degeneration, involving as it does an approximation towards the characters of inorganic substances. And if it be objected that bone is superior to cartilage, because an osseous skeleton is proper to the most highly-developed condition of the individual, it might with as much right be replied that the atrophied thymus gland and the renal capsules almost arrested in their growth, which are normal parts of the more perfect organism, are in a state of advanced development from their fœtal state.

The reproduction of *tendons* is effected very perfectly and speedily in the lower animals; and it appears to take place as perfectly, though perhaps not quite so speedily, in man. We shall not follow our author through the details of the process of conversion of the nucleated blastema, which at first occupies the entire space left by the retraction of the tendon, into the firm fibrous cord, which connects their retracted extremities; since we have already quoted the general account of this metamorphosis when speaking of the development of filamentous tissue. "In every experiment," says Mr. Paget, "one finds cause for admiration at the

manner in which a single well-designed and cord-like band of union is thus gradually formed, where at first there had been a uniform and seemingly purposeless infiltration of the whole space left by the retraction of the tendon." The new tissue may become at last, to all appearance, identical with that of the original tendon, so that even microscopic examination fails to discover the line of original section; as occurred in a case of which a preparation was presented to the College by Mr. Tamplin. But this perfect reparation is comparatively rare, and probably only occurs in very young subjects. In general the new cord looks grayer, less glistening and compact, and less regular, than the proper tendinous substance; and is dovetailed in, as it were, between the fasciculi of the latter at each divided extremity. The strength of this connective band, however, is very great; in one instance, when it was only ten days old, and no more than two lines in diameter, it supported a weight of fifty pounds. The following are the disadvantages which Mr. Paget's experiments lead him to attribute to the section of the tendo Achillis by an open wound, as compared with the subcutaneous method of division:

"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 harm, if it was continued for only a few hours,—a fact which may be usefully remembered when operations must be performed on tendons which it is not convenient to divide unseen." (Lecture vi, p. 134.)

Of the healing of *muscles* subcutaneously divided, Mr. Paget has not much new to say, except that the first tendency seems always to be to a sort of inversion or "tucking-in" of the divided ends, so that nearly all the fasciculi direct their cut ends towards the subjacent bone or fascia, as if to prevent the entire loss of the action of the muscle by securing to themselves fresh points of attachment. The reparative material is the same as in tendon, but seems to be more slowly organized; and, by its gradual contraction, it draws together the retracted portions of the muscle, so that at last they nearly coalesce.

The reunion of divided *nerves* commences on the same plan; but new nerve-tubes gradually extend themselves through the connective tissue, and restore the continuity of the divided fibres. This process of regeneration, however, is slow, twelve months commonly elapsing before any restoration of the function is observed; and we occasionally meet with examples which prove that a more immediate union may take place, when the ends of the nerves remain in approximation. Mr. Paget mentions a remarkable case which fell under his own observation; in which a boy's wrist was half cut through by a circular saw, the flexor tendons, with the radial artery and nerve, and the median artery and nerve, having been

completely divided. After ten days or a fortnight, the conducting power of the median nerve began to return; but the sensations were in some degree confused, as he could not always tell (when blindfolded) whether the thumb or the forefinger was touched; and there were a few and distant small portions of the skin, from which he still derived no sensation at all. This imperfection, as Mr. Paget justly observes, is exactly what we might expect in such a mode of union; for some of the fibres might fail to unite at all, so as to leave the spots insensible from which they proceeded; others might unite with fibres with which they were not properly continuous, so as to confuse the sensations; and among them all, there might be some of which the continuity might be properly restored at once, so as completely to re-establish the function. Another case is related by Mr. Paget, in which the wrist was so nearly severed by the knife of a chaff-cutting machine, that the hand was merely connected with the fore-arm by the ulnar vessels and nerve, and the flexor carpi ulnaris, with a portion of integument about an inch wide; here, too, sensation returned in the thumb in about a fortnight, and the recovery of the motor and sensory powers of the hand was nearly complete. "I need hardly add," he concludes, "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 nerve-functions of the part."

The course concludes with a summary of the chief doctrines which Mr. Paget set himself to elucidate; but as our review will itself have placed before our readers the same material in a different form, we shall quote no more of this than the concluding paragraphs, which bring forward a new and striking argument for the constancy of specific forms.

"Thus the constancy of both the method and the end of the reparative process may confirm us in the belief of the essentiality, we may almost say the immutability, of specific characters. For it shows that with each of all the countless varieties of visible form and structure, which mark the specific characters of living beings, there correspond peculiar internal properties of its constituent matter—properties which are capable of transmission and communication to all that can be incorporated in the living body, and of accumulation in the form of germs; and which, in any way thus transmitted, can manifest themselves in the unchanging power of constructing and composing matter according to the one determined and specific type.

"Thus, by watching the life of any being, in all the varieties of external circumstance and accident, and by seeing that, whatever be the deviation from its perfection into which, by the force of these, it is for a time compelled, it yet reverts to the same specific form,—or, if it fall short of it, assumes no lower one; by watching such a life, we discern an image of the constancy of the law of specific characters; we gain an assurance that matter was not, and is not now, cast without design into the world, to be shaped by the force of chance and circumstance, and to be raised or degraded by their various ebb and flow; that the living occupants of the world have been fashioned and adapted for it, not by it; and that each was from the first endowed with properties that might descend unchanged from one generation to another, and in their immutability might be a symbol of Him who at the first created them, and by whose unchanging Will and Power they have been ever since maintained and still subsist." (Lecture vi, p. 140.)

We must not omit, however, the eloquent conclusion of the first lecture; since we are sure that our readers will agree with us that it combines singular beauty and true philosophy; and in bidding Mr. Paget farewell

for the present, we have only to express the earnest hope that he will favour us with many such courses; convinced, as we are, that their influence on the character of our profession, and more especially on that of its younger members, can be for nothing but good, morally as well as intellectually.

"Let me, then, express my belief that, if ever we are 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 power 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 the facts through which the discovery may be made.

"And 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 complete 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 Ophiura, 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 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 things of which I have been speaking, 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 germ-power developing the body 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 decay of life and death. But, for the human Spirit that has passed the ordeal of the 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 i, pp. 1022-3.)

We shall now follow Professor Owen through his exposition of the series of phenomena which he aims at generalizing; offering, as we proceed, such remarks as may suggest themselves by way of comment or criticism on the statements which he puts forward. In doing this we trust that we shall in no instance lose sight of the claim which he has so worthily acquired to the respectful consideration of any doctrine that proceeds from him; whilst at the same time we assert our own right, which we are sure that he would be one of the last to deny us, to the maintenance of an independent opinion.

After some very pertinent introductory observations, which we are sorry that our space will not allow us to quote, Professor Owen thus enters upon his subject:

"Since the first fiat went forth, the propagation of the species of plants, animals, and mankind has been left to the operation of certain natural secondary causes, which we sum up as the 'act of generation.'

"Botanists and physiologists have observed and progressively analysed the phenomena until they have reduced them to a great degree of simplicity, the essential conditions being the same, or closely similar, in both realms of organic nature.

"With regard to the animal kingdom, the generation of which here concerns us, the essential conditions of the act appear to be a nucleated cell, and the product of a nucleated cell, with the combination of the two: the nucleated cell is the 'germinal vesicle,' and is the essential part of the ovum; the other nucleated cell is the 'sperm-cell,' and its product is the spermatozoon.

"It is essential to the development of the germ that the ovum receive the matter of the spermatozoon: it is then said to be impregnated." (p. 4.)

Now we wish to lay yet more particular stress upon this fundamental fact than our author has done, because we believe that, when reduced to its simplest and most essential form, it is the expression of a law, not merely of the animal but of the entire vegetable kingdom, and therefore of

organized nature at large. We have shown in our second article, that recent investigations in the physiology of the Cryptogamia lead to the belief that the problematical *spermatozoida,* which have been long known to exist in certain tribes of them, are in reality almost universally present, and that they perform the same office in the plants which produce them as they do in animals,—the union of the contents of a "sperm-cell" and a "germ-cell" being essential to the production of a fertile germ. This union we have seen to be effected in a different mode in the flowering plant; but still its essential nature remains the same. And in the "conjugation" of the lowest forms of Cryptogamia we still recognise the same process, although the "sperm-cell" and the "germ-cell" may be to all appearance identical in attributes. This *mixture or reunion of the contents of two cells* is, therefore, the essential condition of what is universally regarded as the "act of generation" throughout the organized world.

But we have seen that the germ thus called into existence developes successive broods of cells, which go on multiplying by the processes of *fission* or *gemmation;* though not, as it would seem, without a limit. These new cells may be all similar to each other, may become detached and live independently, and may thus (in ordinary language) be entitled to rank as distinct "individuals," as in the Palmelleæ, or other simple Algæ and Fungi. Or they may hold together, so as to produce a filament or leafy expansion, in which every cell is still but a repetition of the rest, as in the Confervæ and Ulvæ. Or by slight variations in their mode of multiplication, they may develope a fabric possessing a definite form and a certain degree of heterogeneousness of structure, as in the higher Algæ. Or, to proceed at once to the highest types of vegetation, they may increase for a time by this method of multiplication, so as to form a homogeneous "germinal mass;" this, in its further development, shall first take the form of an almost homogeneous leafy expansion, the single or double "cotyledon;" and from this a heterogeneous fabric, composed of numerous dissimilar parts, may be gradually evolved by a series of morphological and histological changes. Further, the single plant or "phyton" thus developed, extends itself in many instances by the gemmiparous multiplication of similar "phytons," every one of which is capable of existing separately, and is hence to be regarded as entitled to the rank of individuality. But in all these cases the power of cell-multiplication seems to have a limit. If this cannot be definitely assigned in regard to the multiplication of cells by fission, in the inferior Cryptogamia, it is obvious enough in the higher forms of vegetation. The "annual" plant dies down; the so-styled "perennial" gradually loses its capability of producing new buds; and the restoration of the expended power can only take place through an "act of generation." The union of the contents of the "sperm-cell" (pollen-grain) and of the "germ-cell" (embryonal vesicle) again takes place in the ovule; and the result is a vigorous germ, capable of giving origin to a similar multitudinous progeny, in virtue of the new creation of what Mr. Paget would call "germ-power," which this process has called into existence.

These facts, about which we think that there can be no dispute, ought to lead physiologists towards some definite understanding as to the meaning of the term "generation," when used to signify not the *act* but the *result* of the act, not he creation of a new stock but the stock thus

called into existence. Now since physiologists have always been accustomed to speak of the sexual process in animals as "an act of generation," and to regard the evolution of new parts to any extent, which results from the multiplication of the germ-cells by fission or gemmation, and from the subsequent transformations which their descendants may undergo, as an "act of development," we see no good reason for departing from the ordinary signification of these terms, even when this evolution of new parts should proceed to the extent of producing organisms that are capable of maintaining an independent existence. The process by which the individualized cells of a Palmella are called into existence, differs in no respect from that by which the cells of the germinal mass of the higher plant or animal are multiplied, whilst retaining their connexion with each other. Anatomically the homology is perfect; physiologically there are these differences,—that the former are capable of maintaining a separate existence, whilst the latter are not,—that the former are complete in themselves, whilst the existence of the latter is preparatory to that of something else which is to be evolved from them. But so long as the multiplication of parts takes place after a method essentially the same as that which is followed in the evolution of the primal structure, so long must we regard it as entitled to be regarded as a process of "development" rather than as one of "generation;" and this whether the new structure is formed in continuity with the old, or whether it originates in a *gemma* detached at a very early period of its existence; for both these methods, as we have heretofore seen, are but modifications of one and the same, consisting in the mere *subdivision* of the contents of a parent-cell, and in the individualization of each of the portions thus separated. They are, therefore, in complete antagonism to the process of "generation" properly so called; which consists in the *reunion* of the contents of cells thus separated, the individuality of two being merged again into one, to form the germ.

If, then, there be such an antagonism between the two operations,—"development" by subdivision, and "generation" by reunion,—it is surely unwise to confound them together by the indefinite or perverted application of terms; and notwithstanding all that has been said in reply to our criticisms on the theory of "alternation of generations," we still hold to the assertion that the term "generation" can only be rightly applied to the entire phase or series of phases of life which intervenes betweeu one "act of generation" and another; and that however remarkable may be the multiplication and succession of so-called "individuals," this multiplication and succession only repeats on a more extended scale the same processes of "development" as those which are in operation in the multiplication of the individual cells of the Palmellæ, the extension of the filament of a Conferva or of the frondose expansion of an Ulva, and the evolution of the first phyton of the flowering plant from its primordial cell. To use Mr. Paget's language, it is one and the same "germ-force" which is in operation in all these cases; a new "germ-force" can only be created by a new "act of generation;" and all that is the product of the continued action of the same "germ-force" must either be distinguished as belonging to the same "generation," or some other term must be invented to designate it.

It may be said that this is a question rather of words than of realities;

but it is a question in which the right use of terms will be found singularly conducive to the attainment of clear ideas; whilst the indefinite or perverted use of terms will prove, we are confident, a most especial obstacle to the perception of what are really analogous phenomena. Those who designate every fresh bud of a perennial plant as "a new generation," because it is capable of maintaining an independent existence, must needs do the same with regard to every cell of a Palmella or every joint of a Conferva; and we do not see how they can refuse the designation to every successional group of cells which constitutes the germinal mass of higher plants, and multiplies by binary subdivision, or which is concerned in the subsequent multiplication of its parts. It is according to the laws of *homology*, that such designations must be given, in order that they should mean anything consistent and universally applicable; the *physiological* limits of individuality are hard to draw, and often artificial. When, we may ask, does individuality commence in a growing bud? Is not its acquirement of that character a process so gradual, that it cannot be said when it first comes to possess it? How, then, can any definite commencement be assigned to the "new generation," if individuality is to be the sole criterion? Such is a specimen of the difficulties (to which we might add many more) that are involved in the application of the term "new generation" to the multiplication of individuals by any modification of the process of subdivision; instead of restricting it to what we regard as its only legitimate meaning, the origination of a new germ by an "act of generation;" leaving the term "development" to express the whole process by which that germ may be evolved into a single individual, or may give origin to many, whether contemporaneously or successively. But our opponents are quite welcome to use the terms in any sense they think proper, if they will only define that sense in a manner that shall admit of no obscurity, and will keep clearly in view the difference between *sexual* reproduction, or reproduction by the *reunion* of cells, and *non-sexual* reproduction, or multiplication by the *subdivision* of cells.

We may be thought to have wandered far from our subject, in thus parting company with our author at the outset; but we believe that we shall be able to show that the views which we have thus endeavoured to develope, whilst in the main harmonious with those of Professor Owen, tend to simplify and extend our conception of the character of the phenomena, which he aims at reducing to a formal and definite expression. After sketching briefly the mode in which the successors of the first-impregnated germ-cell are gradually metamorphosed into the fabric of the complete animal, he thus continues:

"Not all the progeny of the primary impregnated germ-cell are required for the formation of the body in all animals: certain of the derivative germ-cells may remain unchanged and become included in that body which has been composed of their metamorphosed and diversely combined or confluent brethren: so included, any derivative germ-cell or the nucleus of such may commence and repeat the same processes of growth by imbibition, and of propagation by spontaneous fission, as those to which itself owed its origin; followed by metamorphoses and combinations of the germ-masses so produced, which concur to the development of another individual; and this may be, or may not be, like that individual in which the secondary germ-cell or germ-mass was included.

"It has been found that in proportion as the subjects of anatomical investigation descend in the scale of animal life, the number of the derivative germ-cells and

nuclei which retain their individuality and spermatic power is greater, and the number of those that are metamorphosed into tissues and organs less." (pp. 5-6.)

This last statement is exemplified, in the first instance, by reference to the lower forms of vegetable life in which the fabric consists exclusively of cells; Professor Owen might have added that even in the highest, it is from the cellular portions of the fabric that new growths invariably arise. As an example of the simplest form of animal life, he cites a curious parasitical animal, the *Gregarina*, lately studied by Kölliker, which seems essentially to consist of a single cell, whose animality is accorded on the ground of the vital contractility of its tunic, and the solubility of its cell-wall in acetic acid. We can scarcely regard either of these characters as sufficient for the positive determination of the animality of this curious being; since the cell-walls in many plants possess vital contractility, whilst their primordial utricle (the essential cell-wall) is composed of a protein compound. The strongest indication, as it seems to us, of the animality of this parasite, is the adumbration or shadowing-forth which it exhibits of the characters of the higher entozoa, of whose animal nature no doubt can be entertained. The polygastric Infusoria are regarded by Professor Owen as still essentially retaining the character of parent-cells, although their granular contents have been developed into secondary cells, and some of these have combined and coalesced to form special organs. The Hydra is described as having its body chiefly made up of "retained and unaltered nucleated cells and nuclei, which are identical in all recognisable characters with the progeny of the primary impregnated germ-cell, and which are ready, therefore, when favorable circumstances concur, to repeat the acts of assimilation and spontaneous fission, and, each individually, thus to lay the basis of a new polype."*

These 'derivative germ-cells' are said by Professor Owen to be retained without change, also, in the compound hydriform Polypes and in the parenchymatous Entozoa; a smaller proportion in the Acalephæ and cavitary Entozoa; also in the last segment of the Nais, and the young of other Annelides. "We find," he continues, "derivative germ-cells, and masses of nuclei like those resulting from the final subdivision of germ-cells, retained unchanged at the filamentary extremities of the branched uterus forming the ovaria of the larval Aphides." So, too, in all those cases in which development is arrested at certain stages, in such a manner as to enable the embryo to maintain its own existence for a time, as if it were a completed individual, and to take in a store of material which shall serve for its further development, we find a certain proportion of the 'derivative germ-cells' entering into its constitution,—this being larger in proportion

* We cannot help imagining, from the description of which this is an extract, as well as from the account and figure given by Professor Owen, in his 'Lectures on the Invertebrata,' that he rests this statement chiefly upon the assertions of Corda, which have not been confirmed (so far as we are aware) by more trustworthy observers, furnished with better instruments. To ourselves, the tissue of the Hydra and of its marine congeners has always appeared rather to resemble the "nucleated blastema" of Mr. Paget; and we have recently learned, that Professor Ecker of Basle has formed a very similar idea of its character. He has recognised in the parietes of the stomach three layers, nearly similar to each other in character; each consisting of an amorphous, homogeneous, semi-transparent substance, whose continuity is interrupted by cavities, which inosculate, so as to form an irregular network, in which fluids are seen to move. This network is continuous from one layer to another. The external layer does not present the epidermis described by Corda. The central is distinguished from the external by the green granulations which it includes. The internal is distinguished by brownish granulations, but is not covered with the ciliated epithelium which other anatomists have described. (Ann. des Sci. Nat., Dec. 1848.)

to the earliness of the stage at which the development has been arrested to form the 'larva.' Now in all these cases, we find that reproduction may take place by *fission*, or by *gemmation;* two processes which we agree with Professor Owen in regarding as one and the same. The essential condition of both is, according to him, "the presence of the pellucid nucleus of a derivative germ-cell, as the centre from which all the processes in the formation of the new individual radiate." This may be true to a certain extent; but it seems to us too limited an expression, since it will not apply to the corresponding process in plants. As we have already shown, the *entire endochrome* in the inferior algæ seems concerned alike in the processes of fission and gemmation; the nucleus, which seems to possess a concentration of this power where it exists, being the instrument of it in the higher forms alone of the vegetable cell.

Professor Owen then proceeds to notice some of the principal cases in which reproduction by fission or gemmation alternates with the sexual process; dwelling, of course, particularly upon those curious phenomena which have been grouped together under the title of 'Alternation of Generations.' Of these we particularly considered some in a former article;* and as we purpose to take up others ere long, we need not now dwell upon them. We are very glad to find ourselves strengthened by our author's authority in the fundamental position which we there took up,—namely, that there is no "alternation" in the products of the true "generative" process, but that the intermediate forms are uniformly the results of a fission or gemmation independent of sexual congress, to which he gives the appellation "Parthenogenesis." To this term we have no objection whatever, except that it tends in our apprehension to indicate a relation between two things which are not only *different* but *opposed.* For if we are correct in the view we have taken of the essential nature of these acts, the *reunion* of the contents of the "sperm-cell" and "germ-cell" which is characteristic of the one, and the re-creation of "germ-force" thereby effected, are altogether opposed to the act of *separation* whereby cells are multiplied, and the "germ-force" distributed among them, and thereby progressively weakened.—Again, to speak of a "larval polype," budding off Medusæ, as a "virgin" implies that it is a *female.* Now our notion of a "female" implies the antagonistic action of a "male." The female furnishes the "germ-cell," which is not fertile until it has received the contents of the "sperm-cell." Surely a single cell which is propagating itself by spontaneous fission or gemmation, is neither male nor female; why, then, should we give the latter appellation to a polype which is forming gemmæ without sexual congress? The Hydra produces gemmæ at one period of its existence, indifferently, as it would appear, from any part of its body; at another time it forms germ-cells at one spot and ova at another, by the congress of which a new generation is commenced; if, then, the individual Hydra is to be regarded as a female in virtue of its producing gemmæ, its sex must be metamorphosed to enable it to develope spermatozoa. We still hold to the analogy which we formerly put forth between a zoophyte and a plant.† The gemmæ of the Hydra,

* On the Development and Metamorphoses of Zoophytes, Vol. I, p. 183.

† We meant thereby not a "tree" or composite plant, as represented by Professor Owen (p. 51), and by Professor E. Forbes (Monograph on the Naked-eyed Medusæ, p. 87); but a plant of simplest construction, as described in the next paragraph.

or of any budding polype, we take to be the homologues of the leaves, whilst the true generative organs represent the flower. Whilst the plant is merely putting forth its leaves, nobody considers it as possessing sex; it is simply extending itself by cell-multiplication. It may afterwards develope both kinds of sexual organs, or only one, and this one may be male; how, then, can the plant have been properly female in the earlier stage of its life?

Professor Owen does not seem insensible to the justice of this comparison; but he escapes from its consequences by representing even the simplest plant as an assemblage of individuals. Every leaf, every petal, every stamen, every carpel, is in his apprehension entitled to rank as a distinct being; notwithstanding that the sum of the actions of all of them is necessary to make up the idea of the life of a Plant, and that neither leaf, petal, stamen, nor carpel can maintain an independent existence, except in a few rare cases. Such cases, however, he adduces in support of his argument; urging that, because the leaf of the Bryophyllum and of some other plants can develope buds from its crenated margins, each leaf must be considered as a distinct individual. Now if we look to what a part can develope or *become*, instead of to what it *is*, as our test of individuality, we shall find ourselves reduced to a state of great perplexity. For not merely the entire leaf of the Bryophyllum, but a mere fragment of a leaf (as we have ourselves witnessed), can produce buds under favorable circumstances; and consequently, even the single leaf is to be regarded as an aggregation of individuals. So, again, as the Hydra can produce buds not merely when its body is entire, but as, when it has been minced up into thirty or forty pieces, every fragment may be developed into a new Hydra, we must, if Professor Owen's reasoning be adopted, regard the single Hydra as really an aggregation of individuals. The fact is, as we have already remarked, that the limits of individuality are hard to define; and whatever test we set up will lead, when rigidly applied, to results for which we are scarcely prepared. And hence we think that we should not base our fundamental notions of the reproductive process upon the question, whether or not the several parts of a composite structure are to be considered as distinct individuals? If we reduce our "ideal plant" or "phyton" to its simplest possible elements, the "idea" will still involve as its components, not merely the leaf, but the root, and not merely the leaf and root, but the pollen-grain or the ovule. All these parts, which subdivide the functions performed by the single cell of the Protococcus, must be present to make up a complete phyton; and although a leaf or a fragment of the leaf may be so "potentially," because it is capable of developing the rest, it is not so "actually," any more than a fragment of a Hydra is a complete Hydra.

A considerable portion of Professor Owen's second lecture is devoted to a comparison between his doctrine of "Parthenogenesis," Steenstrup's doctrine of the "Alternation of Generations," and the modification of the latter which we offered in the article before alluded to. In many respects he agrees with us,—fully recognising the importance of the distinction between the "oviparous," or "sexual," and the "gemmiparous" forms of reproduction, and admitting all the applications which we made of the latter to the relation of the Polypes and Medusæ. But he considers that the single or multiple offshoot which results from each act of gemmiparity or "parthenogenesis," should rank as a "new generation," and

that the parent or "stock" should be regarded as a "female." And he brings every case of the kind under his general statement, that the condition of the parthenogenetic process is "the retention of certain of the progeny of the primary impregnated germ-cell, or, in other words, of the germ-mass, unchanged in the body of the first individual developed from that germ-mass, with so much of the spermatic force inherited by the retained germ-cells from the parent-cell, or germ-vesicle, as suffices to set on foot and maintain the same series of formative actions as those which constituted the individual containing them." (p. 72.) These positions we shall now successively examine.

Professor Owen lays especial stress upon the case of the Aphides, as demonstrating the female sexuality of the parent-stock, and as proving the right of the successive broods to the title of "new generations;" and he seems to think that he either forces us to deny the parallelism of the phenomena, or proves the fallacy of our position by a *reductio ad absurdum*. Now we by no means deny the parallelism of the phenomena; on the contrary, we had previously been ourselves prepared to maintain the gemmiparous nature of the non-sexual production of the successional broods of aphides, until informed by Professor Milne-Edwards that what he believed to be true *ova* had been found in their ovaries. We are quite ready to accept Professor Owen's statement, that "the contents of the ovarian tubes differ in the oviparous and in those of the viviparous females; inasmuch as they contain oval masses of granules or nuclei comparable to the germ-mass in its state of minutest subdivision, in the virgin aphides, and not ova with the germinal vesicle, as in the oviparous females;" and to recognise with him the essential conformity between the production of the successional broods of aphides, and the budding of polypes from the sides of the Hydra. But we still maintain that the so-called "virgin" or "viviparous" aphides are *not* females; and we shall be much disappointed if we do not prove this even to the satisfaction of Professor Owen himself. For we must not here look to the conformation of the reproductive apparatus generally, but to its *essential* characters, as no one knows better than the learned Professor. When he meets with a Medusa, for example, with certain plicated membranous folds in the interior of the four chambers that surround the mouth, on what does his determination of its sex depend? Simply upon the fact, that imbedded in these membranous folds are either "sperm-cells" or "germ-cells." If the former, the animal is a male; if the latter, it is a female. The apparatus which ministers to the development of these essential parts is here morphologically the same in both; a clear proof that it alone does not afford a proper sexual character. In higher animals we usually find this apparatus assuming different forms, according to the purpose for which they are developed; but these different forms do not constitute the essence of the sexual character, which still lies in the production of "sperm-cells" on the one hand, or of "germ-cells" on the other. It is quite true that the reproductive apparatus in the viviparous aphides morphologically resembles that of the oviparous or true females; but it is easy to see the purpose of this, namely, the maturation of the gemmæ by nourishment supplied from the stock; and this teleological and purely *formal* resemblance does *not* involve that which is *essential*. For if we call a certain apparatus an ovarium because it produces ova, then it is *not* an ovarium if it does *not* produce ova; and it is

almost as much a misnomer to apply this term to the reproductive apparatus of the viviparous Aphis, which developes not ova but gemmæ, as it would be to give it to the chambers surrounding the mouth of a male Medusa, which contain not ova but spermatic cells. If the viviparous Aphis budded forth its gemma on the exterior of its body, no one would any more think of calling it a "female," than of applying this term to the budding Hydra. It is only because the bud is formed at the top of a set of tubes which resemble in *form*, but not in *essence*, the ovarium of the true female, that Professor Owen, in common with other naturalists, assigns to the gemmiparous Aphis the female character. That he is led, by his own application of this doctrine to the vegetable kingdom (p. 45), to attribute the female character to a budding plant whose sexual organs may be male only, may perhaps be regarded by some physiologists as a *reductio ad absurdum* of *his* doctrine of sexes.

But Professor Owen further argues, that "the growth by cell-multiplication producing a bud, instead of being 'altogether distinct from' the growth by cell-multiplication in an egg, is essentially the same kind of growth or developmental process" (p. 45); and he seems to think that by overlooking this fact, we have made the distinction between the oviparous and gemmiparous processes a great deal stronger than it really is. Now we have nowhere said or implied, as might be supposed from his use of our words, that the development of a new individual from a *gemma* by cell-multiplication differs in any essential respect from the developmental process which is seen in the formation of the germinal mass by the fission of cells in the ovum. On the contrary, we have always regarded them, and have been accustomed to describe them, as one and the same; and we lay great stress upon this correspondence, for reasons which will presently appear. It is between the *origin* of the first cell of the *gemma*, and that of the first cell of the *ovum*, that we hold the essential difference to consist; and the importance of this difference appears to us to have been entirely overlooked by Professor Owen, who evidently aims at approximating the two processes, so as to strengthen his argument for the *female* character of any gemmiparous being. If we are right, however, in the statements we have already made on this point, we think that no doubt can remain that the two processes are, as we formerly affirmed them to be, "altogether distinct," the one consisting in division, the other in reunion; at the same time, we admit that we did not on that occasion *define* this difference as clearly as we have now done; simply because our perception of its essential character was not then so precise as it has since been rendered by the progress of discovery in vegetable physiology.* If, on the other hand, any of our facts are inaccurately stated, we shall gladly receive any correction that may bring them nearer to the truth.

Instead, then, of calling the "viviparous" Aphis a "female," we simply speak of it as "gemmiparous," and deny it any real sexual character, in spite of its possession of organs having the *form*, though not the *essence* of the female ovaries. And this denial is fortified by the consideration,

* Professor Owen has done us the honour to acknowledge the justice of our remark upon the inaccuracy of the statement which appeared in his published Lectures, that the polype-bud of the Hydra is developed from an *ovum*. We, on our parts, are quite ready to admit that our definition of the essential character of gemmation as that of "continuous development from the parent," was imperfect, and open to the criticisms which he has passed upon it; and we thank him for having given us the opportunity of putting forward our doctrine in a less exceptionable form.

that if we assign the female character to any organism that produces new individuals by gemmation, we must attribute it not merely to the budding Hydra but also to the budding leaf-plant; not merely to the entire leaf of a Bryophyllum, but also to a fragment of it; and, descending to the simpler plants, to the extending filament of a Conferva, or to the subdividing cells of a Palmella; and hence, in fact, to *every* cell undergoing fission, or extending itself by gemmation, and thus even to the component cells of the germinal mass. The employment of the designation "female" after this fashion, is altogether a perversion of its *usual* meaning; for it is at present applied to *one* of the *two* sexual organisms, by the concurrence of which in the "act of generation" a new germ is produced; and is the antagonist, or rather the complement, of "male." Professor Owen, on the other hand, would regard every "reproductive" individual as a female; and looks for its male complement in the spermatic force derived from an *antecedent* act of generation. But this latter assumption seems to us rather hypothetical; and we shall presently show that we have no reason to regard any such remnant of the original spermatic force as being more specially concerned in the production of gemmæ, than it is in that reparation or reproduction of parts which may occur in the male among higher animals, just as well as in the female.

In regard to the question whether or not the successive broods of Aphides which result from the repetition of the process of gemmation constitute so many "generations," we freely admit that we may appear to refuse to the term its natural sense, and are taking a position in which we stand alone, in maintaining that they are *not* entitled to that rank. This, however, is more a question of mere words than the other. We think it most philosophical to apply the term "generation" to the whole product, whether single or multiple, contemporaneous or successional, of an "act of generation;" because we find that these phenomena can be best compared, and their true relations determined, when they are arranged according to the principle involved in that idea. The case of the Aphides certainly appears an extreme one; but it does not essentially differ from that of the Hydra. The buds are internal instead of external; and they are developed and nourished in the interior of the body of the parent, so as to arrive at maturity before they come forth, instead of sprouting from the exterior, and obtaining their own food even before their detachment. And through the Hydra we are conducted to cases as extreme in the other direction; for it would be easy to show, that if the successional polypes propagated by gemmation from a single Hydra are so many "generations," so also are the successional cells produced in the polygastric Infusoria and the simplest Algæ, by the subdivision of a single individual; and if these be admitted to the title, we do not see how it can be refused to the similar succession in the filament of a Conferva or the frond of an Ulva; from which the transition is direct (as Professor Owen has himself urged) to the self-multiplying successional cells of the germinal mass; and thence onwards to every case of cell-multiplication in the growing organism. If Professor Owen, and those who take the same view, should object that the "new generation" only comes into existence when new "individuals" are produced, we have not only to reply (as we have already done) that the limits of individuality are too difficult to define, for the establishment of so important a distinction as that between one "generation" and another;

so that perhaps no two of them would agree as to the point at which the line should be drawn in the series we have just indicated; but we will go further, and assert that in the increase of the germinal mass, up to the stage at which its component cells first begin to exhibit a difference of attributes, there is really as complete a generation of "individuals" as in the propagation of the Polygastrica by spontaneous fission. For we must look to this mass as it *is*, not at what it is to *become*. We see a single cell subdividing itself into a pair, this pair subdividing itself into four, the four into eight, and so on, precisely as in a Paramæcium or a Protococcus. And each of these new cells is as much entitled to the rank of a distinct "individual," as are the component monads of a Volvox, or the single cells of the higher Palmellæ, in both which cases they are held together by a common investment, and a definite form is given to the cluster by the regularity of the mode of multiplication. For whilst the attributes of all the cells of the germ-mass remain alike, neither can be regarded as in any way dependent on the rest; and we have no reason to doubt that each might go on living and multiplying when isolated from them, provided that its other conditions of existence were not interfered with.

If, then, the successive broods of viviparous Aphides are to be regarded as so many "generations," so also are the successive broods of cells in the "germinal mass;" and if the former case present a *reductio ad absurdum* of our denial of the title to organisms produced by gemmation, the latter does the same in regard to our opponents' application of the term to such successional productions. As there are cases, then, in which either mode of using it runs counter to our ordinary notions, as well as to our accustomed phraseology, we seem left free to choose between them; and we think it will be found that as, in Professor Owen's apprehension as well as our own, all the phenomena of reproduction which intervene between one "act of generation" and another are to be regarded as *developmental results* of that act, whether a single individual only, or a succession of individuals be thus evolved, it will be most convenient and precise, as well as most philosophical, to regard all these results as constituting but *one generation*, and to speak of the formation of new and independent organisms by gemmation as the *reproduction of individuals*, just as we speak of the restoration of members that have been removed as the *reproduction of lost parts*.

We have now to consider the most important of the doctrines sustained by Professor Owen in this publication; and the one which may be regarded as particularly his own; namely, that this *reproduction of individuals* by gemmation, or parthenogenesis, essentially depends on the retention of a portion of the primary germ-mass in the body of the first individual developed from it. He does not profess to have substantiated this affirmation by direct observation in any considerable number of cases, but contents himself with the citation of a number of instances in which the part whence the gemma springs has an obviously cellular composition, and with applying to these the interpretation which he thinks himself justified in putting upon his observations on the Aphides.

"One sees," he says, "such portion of the germ-mass taken into the semi-transparent body of the embryo Aphis, like the remnant of the yelk in the chick. I at first thought that it was about to be inclosed within the alimentary canal, but it is not so. As the embryo grows, it assumes the position of the ovarium, and

becomes divided into oval masses, and inclosed by the filamentary extremities of the eight oviducts. Individual development is checked and arrested at the apterous larval condition. It is plain, therefore, that the essential condition of the development of another embryo in this larva is the retention of part of the progeny of the primary impregnated germ-cell." (p. 70.)

Now we may admit that in the case of the first larval Aphis which results from the true generative act, a portion of the *original* germinal mass is thus retained; but can the same be said of the succession of individuals which take their origin in this first product? It can scarcely be said that the germs which *their* oviducts contain are the very cells supplied by the original germinal mass, and included without metamorphosis in the developed larvæ; they are, indeed, the descendants of those cells; but so also were all those which have been metamorphosed into the various tissues of the larval Aphis itself. Hence what is *peculiar* in the character of the parts from which the germs arise, is rather that they retain the original cellular *type*, than that they are the *actual residue* of those cells which directly inherited any portion of the spermatic influence. And this, we apprehend, will be a truer expression of the fact in its application to the vegetable kingdom. For whilst we find that the cellular parts of a plant are those which give origin to buds, we have no reason to regard these parts as the permanent residue of the original germinal mass; for this is almost entirely expended in the formation of the cotyledons; and although the first buds may originate from what remains of it, we cannot say the same of the subsequent ones, which, like the successional broods of Aphides, are the products of the developmental processes of the first. Nor do we see any proof that in any of the other instances cited by Professor Owen, there is a retention of the actual cells of the germinal mass that resulted from the generative act; for even if this be admitted with regard to the Hydra which first sprung from the egg, it can scarcely be supposed that such cells are shared amongst all the polypes which shoot forth from it, every one of which seems endowed with the same amount of budding power as the first. We are not sure that Professor Owen himself really needs to have his attention called to this point, for the instances we have cited can scarcely have escaped his consideration; but his language appears to us likely to lead his readers to the conclusion, that in *every* case in which a gemma is formed, that gemma originates in one of the cells of the germinal mass, which originally received the spermatic influence, and which has escaped metamorphosis into the tissues of the individual organism, so as to be ready for development into a new one. The more correct expression of the phenomena, as we have hitherto considered them, appears to us to be, that the gemma always originates from a cell; and that this cell may either be one of those constituting the original ovum, or may be a descendant of one of these,—its essential feature in either case being, that it has escaped those histological transformations, which seem incompatible with the retention of the original reproductive power which is proper to the cell. There is no adequate reason, therefore, to consider these cells, any more than those which develope the first individual, as the special inheritors of the "spermatic force."

But we are not sure whether even this statement will hold good with that universality which is essential for the establishment of a law. For we cannot see how any line can be drawn between the phenomena of the

gemmiparous reproduction of entire individuals, and those of that reproduction of parts which occurs in beings that are unable to develope the whole. We need not recapitulate the arguments by which Mr. Paget has so well demonstrated the identity of their essential conditions. In fact, Professor Owen himself appears to admit it; for he cites the reproduction of claws in the lobster, which is stated by Mr. H. Goodsir to commence from little masses of cells at the basal end of the first joint, in proof that "the reproduction of parts in higher animals depends on pre-existing cells retained as such." No one, we think, can doubt that the regeneration of the claw of a lobster, or of the leg of a salamander, are phenomena of the same order with the production of an entire polype by gemmation, who will attentively consider the facts determined by experiment upon the Hydra. For it there appears that nearly every portion of the body* may reproduce the whole, alike in the spontaneous act of gemmation, and in the reparation of injuries; and this after a precisely similar fashion in both cases. On the other hand, the restoration of a portion of bone, tendon, nerve, or areolar tissue, in the higher animals, which cannot regenerate entire limbs, being phenomena of the same order with the reproduction of claws in the lobster, are to be referred to the same category of "gemmation;" and there is nothing in the history of the reproduction of these tissues, which lends the least support to the doctrine that any "residual cells" are requisite as the starting-point. For we here find that the tissues most readily regenerated are *not* those in which the primitive cellular type is most completely retained. Thus we have seen that cellular cartilage is not regenerated; while fibrous tissue, whether in bone, tendon, or areolar structure, is re-formed with great rapidity and completeness. And it also appears that new structures need not originate in the *solid* fabric of the original; for the observations of Mr. Paget render it nearly certain that the *fluids* effused from the vessels, after the receipt of an injury, are capable of giving origin to tissues, and this quite irrespective of any floating cells which may exist in them; so that we quite lose sight of the original germ-mass in these instances. Moreover, of all the organs in the human body, the thymus and thyroid glands, and the supra-renal capsules, are those most directly derived from it; being essentially infoldings of the germinal membrane, as Professor Goodsir has demonstrated (Phil. Trans. 1846); yet we do not find that these parts are distinguished for their regenerative power, even though the cellular type predominates in them. Hence when the phenomena of reparation are taken into the account, we find that the reproductive power cannot be restricted to parts retaining the cellular type, far less to parts in which any residue of the original cells of the germ-mass can be said to exist; and it cannot be even shown that parts

* Professor Owen states, on the authority of Roesel and others, that the budding process pretty constantly takes place from a certain portion of the body of the *Hydra fusca;* which he affirms to be the part "where those nucleated cells are assembled in greatest number, which most closely resemble the secondary or derivative germ-cells in the ovum." Though he cites this as a correction of our statement, that "buds *may* arise from any part of the parent structure," yet it is not so in reality; since we by no means dispute that buds *more frequently* arise from the part in question than from any other, which is all that we understand Roesel to assert. An examination of Trembley's accurate observations and varied experiments will establish our position, we venture to assert, beyond all question. Trembley particularly states, that when a wound was made in the body of a well-nourished Hydra, new buds were peculiarly apt to spring from the cut edges; as if the formative effort had gone on to the production of new individuals, instead of being restricted to the reparation of the original.

which most completely retain the cellular type, or which are most nearly related to the primitive germ-mass, are those in which the reproductive power is the greatest. Consequently the doctrine of Professor Owen fails in its application to the reparative processes among the higher animals; although, if it possess the universality attributed to it by its author, it ought to be as true of them as it is of the production of independent gemmæ in the lowest and simplest.

We shall, in conclusion, briefly sum up the points of agreement and of difference between Professor Owen and ourselves.—1. Starting from the primary fertilization of the "germ-cell" by the "sperm-cell," all the phenomena of formation and reproduction which take place up to the next act of generation are regarded by us both as referable to the same category, that of cell-multiplication by fission or gemmation, which may be termed the *developmental process*.—2. But when this formative process goes to generate a distinct and independent individual, it is considered by Professor Owen as worthy of being ranked under a separate designation, that of "Parthenogenesis;" the stock or being from which the gemma originates is regarded by him as a female, and the gemma itself is ranked as a "new generation." To us, on the contrary, it seems that the stock is of no sex; that the process of gemmation is one antagonistic of sexual production, and ought not to be assimilated to it in any way; that the term, "Parthenogenesis" is inappropriate; and that the term "generation," may be best made to include all that intervenes between one "act of generation" and another.—3. By Professor Owen it is affirmed that the essential condition of the gemmation of new individuals among the lower tribes, or of the reproduction of members in the higher, is the retention of cells resembling those of the germinal mass, and specially impressed by the "spermatic force." To us, on the contrary, it appears that the most that can be said is, that gemmation or reproduction most readily proceeds from unmetamorphosed cells; but that there is no sufficient proof that these cells are more immediately related to those of the germinal mass, or have received any more special share of the spermatic influence, than those which have contributed to the development of the individual fabric: whilst, in the reparative processes of the higher animals, there is not the least proof of dependence on any such cells; the "germ-force" (to borrow Mr. Paget's expression) being diffused through the formative fluids, at least as much as among the solids.

We trust that our readers will not think that we have dwelt at too great length upon a question which may seem too abstract to be of any practical utility. But those of them who may have followed us through this article, will have seen how closely the true comprehension of the phenomena discussed by Professor Owen, is linked on to the scientific understanding of the subject of which his colleague has so ably treated. And if, whilst keeping in mind the essentially practical bearing of the latter, they reflect upon that immortal axiom of Bacon, which sets forth that "the office of science is to shorten the long turnings and windings of experience," we think that no apology will be needed by them for our full discussion of the doctrine of "Parthenogenesis."